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NOTES ON ALGAL NOMENCLATURE. III. MISCELLANEOUS SPECIES OF CHLOROPHYCEAE, PHAEOPHYCEAE AND RHODOPHYCEAE

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The first two papers in this series[1] dealt with certain questions of nomenclature pertaining primarily to South African marine algae. The present article is concerned mainly with extra-South African species which came under consideration in connection with the writer's study of the South African marine flora.

Udotea Flabellum (Ell. et Soland.) Lamouroux, Nouv. Bull. Sci. Soc. Philom. **3**: 186. 1812.

Udotea Flabellum (Ell. et Soland.) Howe, Bull. Torrey Bot. Club **31**: 94. 1904.
Corallina Flabellum Ellis et Solander, Nat. Hist. Zooph. p. 124. *pl. 24, fig. A–C.* 1786.

U. Flabellum is the only species which Lamouroux included in *Udotea* when he founded the genus in 1812. In 1904, Howe made the combination *U. Flabellum* (Ell. et Soland.) Howe on the grounds (Howe, 1907, p. 495, note) that Lamoroux did not really include the species in *Udotea* until 1816 and when he did so he called it *U. flabellata* instead of *U. Flabellum*. A. and E. S. Gepp (1911) in their monograph of the Udoteae and other writers have accepted Howe's reasoning and have credited him with the combination *U. Flabellum*.

Since 1812 is the accepted date of publication of *Udotea* Lamouroux and since *Corallina Flabellum* Ellis et Solander was the only example cited by Lamouroux as representative of his new genus, there seems to be little question that he intended the citation to serve as a transfer. In his paper of 1812, Lamouroux also erected several other genera of marine algae which are still valid, such as *Halimeda, Galaxaura, Liagora, Jania, Amphiroa* and *Melobesia* with examples of known species cited under each. If the precedent set by Howe were to be followed, none of the species referred to these genera by Lamouroux could be considered as having been effectively transferred. Many writers, including Howe

[1] Proc. Nat. Acad. Sc. **28**: 446–451. 1942; Amer. Jour. Bot. **30**: 463–468. 1943.

(1920), have, however, credited Lamouroux with certain of these combinations, as for example, *Amphiroa Tribulus, Jania rubens* and others. It would seem, therefore, that Lamouroux should be regarded as the author of the binomial *Udotea Flabellum.*

Codium dichotomum (Huds.) S. F. Gray, Nat. Arr. Br. Pl. **1.** p. 293. 1821.
Codium dichotomum (Huds.) Setchell, Univ. Calif. Publ. Bot. **16:** 357. 1931.
Spongia dichotoma Hudson, Fl. Angl. ed. 1. p. 489. 1762.
Codium tomentosum (Huds.) Stackhouse, Ner. Brit. ed. 1. p. XXIV. 1797.
Fucus tomentosus Hudson, Fl. Angl. ed. 2. p. 584. 1778.

This species was known for almost a century and a half as *Codium tomentosum* until Setchell pointed out in 1931 that the plant should be known as *C. dichotomum* (Huds.) Setch. Setchell gives a detailed account of the nomenclatural history of the species but in his review of the literature overlooked S. F. Gray's *Natural Arrangement of British Plants* in which the combination *C. dichotomum* was made by Gray (1821).

Codium prostratum Levring, Lunds Univ. Årsskr. N. F. Avd. 2, **34**(9): 16. *fig. 8a–d, pl. 4, fig. 11.* 1937.
Codium Vaughani Børgesen, K. Danske Vidensk. Selsk. Biol. Medd. **15**(4): 70. *fig. 24, 25.* 1940.

From Børgesen's (1940) description and figures of *Codium Vaughani,* it seems clear that this species from Mauritius is identical with the South African plant which Levring (1937) had described three years earlier as *C. prostratum.* The species is very common in certain localities along the east coast of South Africa and its occurrence in Mauritius is not surprising.

Dictyota dichotoma (Huds.) Lamour. var. **intricata** (Ag.) Greville, Alg. Brit. p. 58. 1830.
Zonaria dichotoma var. *intricata* Agardh, Sp. Alg. **1** (1). p. 134. 1820.
Dictyota dichotoma var. *implexa* (Desf.) S. F. Gray, Nat. Arr. Br. Pl. **1.** p. 341. 1821.
Dictyota dichotoma var. *implexa* (Lamour.) J. Agardh, Sp. Alg. **1.** p. 92. 1848.
Fucus implexus Desfontaines, Fl. Atl. **2.** p. 423. 1800.
Dictyota implexa (Desf.) Lamouroux, Nouv. Bull. Sci. Soc. Philom. **1:** 331. 1809; Journ. de Bot. **2:** 43. 1809.

This plant is usually referred to as *Dictyota dichotoma* var. *implexa* (Lamour.) J. Ag. but the epithet *implexa* should be credited to Desfontaines who in 1800 described the alga as *Fucus implexus.* Lamouroux in 1809 transferred *Fucus implexus* to *Dictyota* but made no claim to the authorship of the species. Credit for the ternary combination *D. dichotoma* var. *implexa* must go, as far as the writer has been able to ascertain, to S. F. Gray who in 1821 reduced *D. implexa* (Desf.) Lamour. to the status of variety under *D. dichotoma.* J. Agardh, who is usually credited with the trinomial, made the transfer in 1848(a), some twenty-seven years after it had been made by Gray. However, according to Article 58 of the International Rules of Botanical Nomenclature (1935),

the ternary name *D. dichotoma* var. *implexa* (Desf.) S. F. Gray (1821) is invalidated by *D. dichotoma* var. *intricata* (Ag.) Grev. (1830), which is based on *Zonaria dichotoma* var. *intricata* Ag. (1820).

Zonaria subarticulata (Lamour.) Papenfuss comb. nov.

Dictyota subarticulata Lamouroux, Nouv. Bull. Sci. Soc. Philom. **1**: 331. 1809; Journ. de Bot. **2**: 41. 1809.
Dictyota interrupta Lamouroux, Ann. Mus. Hist. Nat. **20**: 272. *pl. 12, fig. 1.* 1813.
Fucus interruptus (Lamour.) Turner, Fuci **4.** p. 114. *pl. 245.* 1819.
Zonaria interrupta (Lamour.) Agardh, Sp. Alg. **1** (1). p. 137. 1820; Syst. Alg. p. 268. 1824; J. Agardh, Sp. Alg. **1.** p. 111. 1848 (in part); Harvey, Phyc. Austr. **4.** *pl. 190.* 1862 (excl. certain syns.).
Phycopteris interrupta (Lamour.) Kützing, Sp. Alg. p. 564. 1849 (in part); Tab. Phyc. **9.** p. 27. *pl. 67, fig. 1.* 1859.
Zonaria Turneriana J. Agardh, Öfvers. Kgl. Svensk. Vetensk.-Akad. Förhandl. **27**: 438. 1871; Till Alg. Syst. Afd. 1. p. 48. 1872.
Phycopteris angustata Kützing, Tab. Phyc. **9.** p. 28. *pl. 69, fig. 1.* 1859.

In 1809 Lamouroux described *Dictyota subarticulata,* giving as the source of his material "*Ind. Or., Nov. Hol.*" In his later treatment of *Dictyota,* in his *Essai* (1813), Lamouroux substituted the specific epithet *interrupta* for *subarticulata* and at the same time gave as the locality "*Ind. Orient.*" only, omitting the "*Nov. Hol.*" In 1820 Agardh transferred *D. interrupta* to *Zonaria* and the species has since been known as *Z. interrupta.* Since the specific name *subarticulata* antedates *interrupta,* the binomial *Z. interrupta* must yield to the new combination *Z. subarticulata* (Lamour.) Papenf.

In 1834, Suhr recorded a South African alga under the name *Z. interrupta,* and subsequent writers have generally regarded the South African plant as representative of *Z. interrupta.* This plant was described as *Phycopteris cuneata* by Kützing in 1859 but the name was not accepted, owing, no doubt, to the fact that J. Agardh in 1871 contended that the South African plant actually is the *Dictyota interrupta* (or *D. subarticulata*) of Lamouroux and the Australian plant a different (new) species which he described as *Zonaria Turneriana.* J. Agardh's identification of the South African alga with *Dictyota interrupta* seems to be based primarily upon comparison with Lamouroux's (1813) figure of *D. interrupta* and is unconvincing. Although differing anatomically, the Australian and South African plants are very similar in habit and it would be impossible to settle the identity of *D. interrupta* purely on the basis of Lamouroux's description and figure.

As has been mentioned, Lamouroux in 1809(a) gave as the source of his material of *D. subarticulata* the East Indies and Australia, while in 1813, when he called the species *D. interrupta,* he cited the East Indies only. As far as the writer is aware, no subsequent collectors have obtained this species, or one resembling it, from the East Indies, which suggests that this locality may have been given in error. On the other hand, the evidence that the material in question had come from Australia and

not from South Africa is twofold: firstly, in his article in the *Journal de Botanique,* Lamouroux (1809b) gave the names of Thouin and De la Billardière as the persons from whom he had received the material of *D. subarticulata.* The writer can find no record of either of these men having collected in South Africa but it is known that De la Billardière did collect in Australia. Secondly, in the paper containing the description of *D. subarticulata,* Lamouroux (1809a) recorded a number of species from Australia but not a single one from South Africa.

Zonaria cuneata (Kütz.) Papenfuss comb. nov.

Phycopteris cuneata Kützing, Tab. Phyc. **9.** p. 27. *pl. 67, fig. 2.* 1859.

This South African species has passed under the name *Zonaria interrupta* for more than a hundred years, but as was pointed out in the preceding paragraph this name applies to an Australian plant. Kützing in 1859 described the South African plant as *Phycopteris cuneata* but the name has been considered as synonymous with *Z. interrupta.*

Zonaria Harveyana (Pappe ex Kütz.) Areschoug, Phyc. Cap. p. 26. 1851.

Phycopteris Harveyana Pappe ex Kützing, Sp. Alg. p. 564. 1849; Tab. Phyc. **9.** p. 26. *pl. 66, fig. 2.* 1859.

Homoeostrichus multifidus J. Agardh, Anal. Alg. Cont. 1. p. 15. 1894.

Zonaria multifida Harv. ex J. Agardh, Sp. Alg. **1.** p. 109. 1848; Till Alg. Syst. Afd. 1. p. 46. 1872 (not *Z. multifida* (Sm.) Agardh, Sp. Alg. **1**(1). p. 135. 1820).

The genus *Homoeostrichus* was erected by J. Agardh in 1894 to receive four species which had previously been included under *Zonaria.* The first species listed under *Homoeostrichus,* and presumably the type of the genus, is a South African plant which J. Agardh had described in 1848 as *Zonaria multifida,* a manuscript name of Harvey.

The primary feature distinguishing *Homoeostrichus* from *Zonaria* is a difference in structure of the superficial tissue of the frond: in *Homoeostrichus* the cells composing this layer are of the same width as those of the medulla, while in *Zonaria* the superficial cells become divided by a vertical longitudinal wall and in transverse sections of the frond two superficial cells consequently correspond in width to each of the underlying medullary cells.

It is obvious that this distinction between the two genera, even if constant, is of minor importance and it seems best to unite *Homoeostrichus* with *Zonaria.* Justification for the suppression of *Homoeostrichus* is furnished, furthermore, by the fact that in *Z. Tournefortii,* the type of *Zonaria,* the superficial cells are not always divided by a vertical longitudinal wall while in *H. multifidus,* the type of *Homoeostrichus,* these cells not infrequently are divided by such a wall.

As has been stated, *H. multifidus* is based on *Zonaria multifida* Harv. ex J. Agardh (1848a). The latter binomial is invalidated, however, by the earlier homonym of *Z. multifida* (Sm.) Agardh (1820). It is there-

fore necessary to employ the specific name *Harveyana* under which the plant was described by Kützing in 1849 as *Phycopteris Harveyana.*

Zonaria spiralis (J. Ag.) Papenfuss comb. nov.
Homoeostrichus spiralis J. Agardh, Anal. Alg. Cont. 2. p. 89. 1894.

Zonaria flabellata (Okam.) Papenfuss comb. nov.
Homoeostrichus flabellatus Okamura, Icon. Jap. Alg. **6**(6). p. 57. *pl. 279. fig. 11–13.* 1931.
Homoeostrichus Sinclairii (H. et H.) J. Ag., Okamura, Icon. Jap. Alg. **4**(10). p. 192. *pl. 199, fig. 1–4.* 1923.

In consequence of the subordination of *Homoeostrichus* to the synonymy of *Zonaria,* it is necessary to transfer the preceding two species to the latter genus.

Ecklonia radiata (Ag.) J. Agardh, Sp. Alg. **1**: 146. 1848.
Laminaria radiata Agardh, Syn. Alg. Scand. p. XIII. 1817; Sp. Alg. **1.** p. 113. 1820.
Fucus radiatus Turner, Fuci **2.** p. 161. *pl. 134.* 1809 (not *F. radiatus* Good. et Woodw., Trans. Linn. Soc. **3**: 202. 1797).

This species is usually referred to as *Ecklonia radiata* (Turn.) J. Ag., the specific epithet being based on *Fucus radiatus* Turner. Since this binomial of Turner (1809) is invalidated by the earlier homonym of *F. radiatus* Good. et Woodw. (1797), the authorship of the species must be credited to Agardh who in 1817 called the plant *Laminaria radiata.*

Ecklonia biruncinata (Bory) Papenfuss comb. nov.
Laminaria biruncinata Bory, Dict. Class. Hist. Nat. **9**: 190. 1826; *in* Duperrey, Voy. Coquille p. 101. *pl. 10.* 1828 (as *L. bironcinata*).
Ecklonia exasperata (Turn.) J. Agardh, Sp. Alg. **1.** p. 146. 1848.
Fucus radiatus β *exasperatus* Turner, Fuci **2.** p. 161. 1809.

In a recent article the writer (Papenfuss, 1940, p. 210) gave his reasons for considering this plant as an independent species rather than as a variety or a form of *Ecklonia radiata.* He used the name *E. exasperata,* which is based on *Fucus radiatus β exasperatus* Turner (1809), but if this entity is treated as a species, it is necessary to employ the name *biruncinata* under which the plant was described by Bory in 1826 as *Laminaria biruncinata.*

Himanthalia elongata (L.) S. F. Gray, Nat. Arr. Br. Pl. **1.** p. 389. 1821.
Himanthalia elongata (L.) Setchell, Univ. Calif. Publ. Bot. **16**: 358. 1931.
Fucus elongatus Linnaeus, Sp. Pl. ed. 1, **2.** p. 1159. 1753.
Himanthalia lorea (L.) Lyngbye, Tent. Hydr. Dan. p. 36. 1819.
Fucus loreus Linnaeus, Syst. Nat. ed. 12, **2.** p. 716. 1767.

This species was known as *Himanthalia lorea* for more than a century until Setchell pointed out in 1931 that the specific epithet *elongata* antedates *lorea* and the plant should be known as *H. elongata* (L.) Setch. Setchell, however, overlooked the fact that the combination *H. elongata* had already been made by S. F. Gray in 1821.

Zanardinula Andersoniana (Eaton ex J. Ag.) Papenfuss comb. nov.

Prionitis Andersoniana Eaton ex J. Agardh, Sp. Alg. **3**(1). p. 159. 1876; Kylin, Lunds Univ. Årsskr. N. F. Avd. 2, **37**(2): 11. 1941.

Zanardinula australis (J. Ag.) Papenfuss comb. nov.

Phyllotylus australis J. Agardh, Öfvers. Kgl. Svensk. Vetensk.-Akad. Förhandl. **4**: 9. 1848.

Prionitis australis (J. Ag.) J. Agardh, Sp. Alg. **2**(1). p. 188. 1851; Kylin, Lunds Univ. Årsskr. N. F. Avd. 2, **37**(2): 12. *pl. 3, fig. 10.* 1941.

Zanardinula linearis (Kylin) Papenfuss comb. nov.

Prionitis linearis Kylin, Lunds Univ. Årsskr. N. F. Avd. 2, **37**(2): 12. *pl. 4, fig. 11.* 1941.

Zanardinula filiformis (Kylin) Papenfuss comb. nov.

Prionitis filiformis Kylin, Lunds Univ. Årsskr. N. F. Avd. 2, **37**(2): 13. 1941.

The change in name of the four preceding species is necessitated by the fact that the generic name *Prionitis* J. Agardh (1851) is invalidated by *Prionitis* Adanson, a genus of flowering plants described in 1763. J. De Toni (1936) has proposed the name *Zanardinula* for the genus of algae.

Gigartina Hystrix (Ag.) Setchell et Gardner, Univ. Calif. Publ. Bot. **17**: 295. 1933 (excl. syn. Kütz.).

Grateloupia Hystrix Agardh, Sp. Alg. **1**(2). p. 223. 1822; *in* Presl, Reliquiae Haenkeanae p. 9. 1825.

Chaetangium Hystrix (Ag.) Kützing, Sp. Alg. p. 793. 1849.

Gigartina Radula var. *Radula* J. Agardh, Sp. Alg. **2**(1). p. 278. 1851 (in part).

Gigartina Radula var. *Hystrix* (Ag.) J. Agardh, Sp. Alg. **3**(1). p. 203. 1876 (in part).

This species was described by Agardh in 1822 from material collected by Haenke. As the source of the material, Agardh cited (with a query) the Cape of Good Hope. The species was later included by Agardh in the list of algae collected by Haenke (cf. Presl, *op. cit.* p. 8–12) on the Spanish expedition under the command of Malaspina. In 1849 Kützing transferred *Grateloupia Hystrix* to the genus *Chaetangium*. J. Agardh in 1851 included the plant in his var. *Radula* of *Gigartina Radula* but in 1876 made it an independent variety under *G. Radula*. Setchell and Gardner in 1933 restored the entity to specific rank under *Gigartina*. It should be noted, however, that none of the writers subsequent to Agardh has seen the type or authentic material of *Grateloupia Hystrix*.

While examining the South African algae in Herb. Agardh, search was made for the type of *Grateloupia Hystrix* but no specimen with this inscription in the hand of C. Agardh was to be had. The specimens which J. Agardh referred to *Gigartina Radula* var. *β Hystrix* occur under the following numbers: 23825 ("*e C. B. Spei dedit* Turner"), 23826–23829, 23831 ("Pappe"), 23833 ("*ded.* Turner"). Of these specimens, numbers 23825 and 23829 are representative of *Gigartina polycarpa* (Kütz.) Setch. et Gard. while the remaining numbers are of *G. bracteata* (Gmel.) Setch. et Gard.

Agardh's description of *Grateloupia Hystrix* is very inadequate and the identity of the species can only be established from an examination of the type, presumably in the Bohemian Museum at Prague. Since South Africa was not visited by the Malaspina Expedition, it seems most unlikely that the Cape was the source of Haenke's material of *G. Hystrix*. It is not unlikely that the material was collected at Monterey, California, where Haenke apparently collected several marine algae (cf. Kylin, 1941, pp. 10, 12, 16, 28).

In this connection it might be pointed out that in his list of the algae of Haenke, Agardh described two species of *Cystoseira, C. australis* and *C. caudata*, which seem to have escaped notice entirely. Another record of interest is that of *Fucus compressus*. This little-known species was first described by Agardh in 1824. As the source of his material, Agardh gave "*in mari australi*" but he gave no information as to the collector. Since several of Haenke's algae were first described by Agardh in 1822 or in 1824, it seems likely that Haenke might have been the collector of the type material of *F. compressus*. It is not improbable, moreover, that the specimens were secured at Monterey, the source of several of Haenke's specimens which were incorrectly designated by Agardh as having come from "*mari australi*" (cf. Kylin, 1941). If this is correct, *F. compressus* may prove to be representative of a species of Fucales of the Californian coast.

Gymnogongrus vermicularis (Ag.) J. Agardh, Sp. Alg. **2**(1). p. 323. 1851 (excl. syn. *Gracilaria concinna* Mont.)

Sphaerococcus vermicularis Agardh, Syn. Alg. Scand. p. XVII. 1817; Sp. Alg. **1**(2). p. 311. 1822.

Fucus vermicularis Turner, Fuci **4**. p. 61. *pl. 221.* 1819 (not *Fucus vermicularis* Gmelin, Hist. Fuc. p. 162. *pl. 18, fig. 4.* 1768).

Chondrus capensis Kützing, Sp. Alg. p. 738. 1849 (excl. syns.); Tab. Phyc. **17**. p. 17. *pl. 59, fig. a, b.* 1867 (not *Gymnogongrus capensis* (Ag.) J. Ag.).

This South African alga is currently known as *Gymnogongrus vermicularis* (Turn.) J. Ag., the specific epithet being based on the *Fucus vermicularis* of Turner. The name *Fucus vermicularis* Turner (1819) is invalid, however, since it is a later homonym of *Fucus vermicularis* Gmelin (1768). According to Article 69 of the International Rules of Botanical Nomenclature (1935) the binomial *Gymnogongrus vermicularis* would be valid, however, if the specific epithet were treated as a new name of Agardh[2] (1817, p. xvii) — *Sphaerococcus vermicularis* — and not as a transfer from *Fucus vermicularis* Turner.

The source of Turner's *Fucus vermicularis* is unkown and some uncertainty has existed as to whether his specimen actually is representative of the South African plant. An examination of the specimen (in Herb. Kew) has convinced the writer, however, that Turner's plant is representative of *Gymnogongrus vermicularis*.

[2] Agardh (*loc. cit.*) cites Turner's plate of *Fucus vermicularis* which indicates that parts of volume 4 of Turner's *Fuci* appeared at least as early as 1817. The title page of this volume is dated 1819.

Botryocladia Skottsbergii (Børg.) Papenfuss comb. nov.

Chrysymenia Skottsbergii Børgesen, *in* Skottsberg, Nat. Hist. Juan Fernandez and Easter Island **2**(3) Botany: 307. *fig. 49, 50.* 1920.

As can be seen from Børgesen's (1920) description and figures of *Chrysymenia Skottsbergii*, the species is representative of *Botryocladia* Kylin (1931), a segregate from the genus *Chrysymenia.*

Gastroclonium ovatum (Huds.) Papenfuss comb. nov.

Fucus ovatus Hudson, Fl. Angl. ed. 1. p. 468. 1762.
Gastroclonium ovale (Huds.) Kützing, Phyc. Gen. p. 441. 1843.
Fucus ovalis Hudson, Fl. Angl. ed. 2. p. 573. 1778.
Fucus vermicularis Gmelin, Hist. Fuc. p. 162. *pl. 18, fig. 4.* 1768 (not *Fucus vermicularis* Turner, Fuci **4.** p. 61. *pl. 221.* 1819).

As was pointed out above, under *Gymnogongrus vermicularis,* the binomial *Fucus vermicularis* Gmelin (1768) invalidates *F. vermicularis* Turner (1819). In tracing the present status of *F. vermicularis* Gmelin, it was of interest to find that this name is included in the synonymy of *Gastroclonium ovale* (Huds.) Kütz., which is based on *Fucus ovalis* Hudson. Since *F. vermicularis* Gmelin (1768) antedates *F. ovalis* Hudson (1778) by ten years, it is obvious that the specific epithet of Hudson has no legal status.

When describing *Fucus ovalis* in 1778, in the second edition of his *Flora Anglica,* Hudson made no reference to the first edition (1762) of this work. Examination of the first edition shows, however, that the species was originally described in this edition under the name *Fucus ovatus.* Since this name antedates *F. vermicularis* Gmelin by several years and since it seems to be the oldest name for the species, it becomes necessary to make the combination *Gastroclonium ovatum* (Huds.). There is no clue in the second edition of *Flora Anglica* as to Hudson's reasons for substituting the name *ovalis* for *ovatus* but it seems likely that he considered the former more appropriate. Subsequent writers have invariably adopted the name *ovalis* and the binomial *Fucus ovatus* has, with few exceptions, not been included in the synonymy of the species. Of the numerous works consulted, the synonym *F. ovatus* Huds. was met with only in Withering's *Arrangement of British Plants* (ed. 3, **4.** p. 113. 1796; ed. 6, **4.** p. 136. 1818 — the only editions available to the writer).

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NEW SPECIES AND VARIETIES OF WISCONSIN ALGAE

G. W. Prescott

The history of glaciation in central North America, together with other geological and geographical factors, has been such that Wisconsin is richly endowed with a great variety of lakes, ponds, and drainage systems. A considerable number of lakes, especially in the northern uplands of the state, are land-locked, while many others are the flowage or drainage type. The countless bodies of water, so characteristic of the north central states, exhibit marked differences in their chemical and physical properties. These dissimilarities together with certain hydrographical features make possible a varied and abundant algal flora in Wisconsin which has become well known through the published reports of G. M. Smith (1916, 1918, 1920, 1924).

For more than three decades E. A. Birge and C. Juday, together with their co-workers have carried on limnological studies of the inland lakes of Wisconsin. It is in relation to their work that Smith (1920–1924) undertook his survey of the plankton algae, making rather exhaustive studies of the flora, especially from the lakes in which Birge and Juday had been conducting their investigations. Professor Juday, Director of the Trout Lake Limnological Laboratory, invited the author to extend the survey of Wisconsin algae from both taxonomic and ecological viewpoints. Consequently, special attention has been directed toward the attached or littoral algae. Collections and field work were carried on during three summers, mostly in the northeastern and northwestern lakes regions. A full report on this survey, which will also include the algae previously reported from the state, is forthcoming.

Many forms which appeared in the author's collections and in others loaned to him, are new records for North America. The following thirty species and varieties apparently are novelties. The desmids were collected and identified but because they are so numerous, descriptions of them are deferred for a subsequent report. The diatoms are being studied by Mr. Paul Conger of the Carnegie Institution, Washington, D. C. All the other algal groups were considered, however, and they are represented in the state by approximately 1,025 species and varieties, exclusive of the desmids.

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PHYLUM CHLOROPHYTA

A. CHLOROPHYCEAE

CHLAMYDOMONADACEAE

Chlamydomonas polypyrenoideum, sp. nov.

PL. 1, FIG. 1–2.

Cellulae ovoideae vel ellipsoideae, carentes papilla apicali et vagina gelatinosa; chloroplaste calyce denso parietali cum incisione alta in medio; pyrenoidibus multis (12–16), sparsis; macula oculari non observata; cellulis 8–10 μ lat., 9–12 μ long.

Cells ovoid to ellipsoid, without an apical papilla; gelatinous sheath lacking; chloroplast a dense parietal cup with a deep median invagination; pyrenoids many (12–16), scattered; pigment spot not observed; cells 8–10 μ in diameter, 9–12 μ long.

Rare in the plankton of Weber Lake, Vilas County.

The differentiating character of this species is the large number of pyrenoids. Some other *Chlamydomonas* species have several such organs but the form of the chloroplast, the shape of the cell and other morphological differences prevent the Wisconsin form from being assigned to them.

TETRASPORACEAE

Tetraspora lamellosa, sp. nov.

PL. 1, FIG. 3.

Thallus irregulariter lobatus et bullatus; libere natans; cellulis sphaericis, in paribus dispositis, cum membranis crassis et vaginis lamellatis gelatinosisque, distinctis et non confluentibus in gluten colonicum; pseudociliis delicatissimis, 20–30-plo diametro cellulae longioribus; chloroplaste lamina dense parietali paene totum membranum tegente, cum una pyrenoide; cellulis 9–10.5 μ lat.

Thallus irregularly lobed and saccate; free-floating; cells spherical, in twos, with thick walls and gelatinous lamellate sheaths, distinct and not confluent with the colonial mucilage; pseudocilia very fine, 20–30 times the diameter of the cell in length; chloroplast a dense parietal plate covering almost the entire cell wall, with 1 pyrenoid; cells 9–10.5 μ in diameter.

The species differs from others by the possession of distinct lamellated cell sheaths and the extraordinarily long pseudocilia. In the former character it resembles some species of *Gloeocystis*.

Schizochlamys compacta sp. nov.

PL. 1, FIG. 4–6.

Massa plantae microscopica, cum glutine solido, homogeneo et claro tegumento limitato; cellulis globosis cum apice conspicuo glutinis in uno latere locato, dividente fissura membrani quae unum fragmentum, rare 2, relinquit; apice glutinis persistente in antiquo membrano matris, cellulis filialibus habentibus singulos apices glutinis plerumque contingentes; una chloroplaste parietali cum pyrenoide; cellulis 7.4–11 μ lat.

Plant mass microscopic, mucilage firm, homogeneous and bounded by a definite tegument; cells globose with a conspicuous cap of gelatine at

one side, dividing by a splitting of the cell wall leaving one fragment (rarely two); the mucilage cap persisting on the old mother cell wall, daughter cells with respective caps of mucilage usually in contact; one parietal chloroplast with a pyrenoid; cells 7.4–11 μ in diameter.

Rare in a small pool within a *Sphagnum* bog near Manitowish River fish hatchery, Vilas County.

This plant should be compared with *S. delicatula* West which forms but a single fragment of the cell wall upon liberation of daughter cells. It differs in the definiteness of shape of the mucilage, in the larger cells, and in the mucilage cap on the cell wall which seems to be a constant character.

ULOTRICHACEAE

Ulothrix cylindricum sp. nov.

PL. 1, FIG. 7.

Fila longa, curva, et leviter implicata; cellulis elongato-cylindricis, 11–12.5 μ lat., 2¼–3-plo longioribus diametro, membranus parallelis et nullas constrictiones membranis transversis habentibus; chloroplaste fascia lata, paene pari longitudine cellulae et plicata ad mensuram ¾ peripheriae parietalis; pyrenoidibus 2–5.

Filaments long, curved, and slightly entangled; cells elongate-cylindric, 11–12.5 μ in diameter, 2¼–3 times as long as wide, the walls parallel and without constrictions at the cross walls; chloroplast a broad band, nearly equal to the cell in length and folded about ¾ of the wall circumference; pyrenoids 2–5.

In the plankton of Cecelia Lake, Vilas County.

This species should be compared with *U. æqualis* Kuetz. which has thick walls, shorter cells, fewer pyrenoids and a different form of chloroplast. Many species of this genus have been described and there is a great confusion in the synonymy. It is highly possible that the Wisconsin plants agree with some previously described varieties of known species. The proportions of the cell, the form of the chloroplast and the number of pyrenoids seem to separate our plants from described species as far as determined by available herbarium material.

Geminella crenulatocollis sp. nov.

PL. 1, FIG. 8.

Planta filum uniseriatum cellularum irregulariter ovoidearum, subquadratarum, vel oblongarum cum membranis lateralibus emarginatis, crenulatis, aut undatis, truncatis aut late polis rotundatis, cum rugis et iugis interdum in membranis lateralibus visis; cellulis inclusis in vagina lata gelatinosa, in paribus linearibus, sed saepe aequaliter locatis; chloroplaste lamina parietali irregulariter formata et plicata, quae paene totum cylindricum in membrano fingit, saepe monstrante iugum aut labrum alatum radialiter ad membranum extendens; pyrenoide una, in centro locata; cellulis 12–15 μ lat., 18–24 μ long.

Plant a uniseriate filament of irregularly ovoid, subquadrate or oblong cells with emarginate, crenulate, or wavy lateral walls, truncate or broadly rounded at the poles, with folds and ridges sometimes present in the lateral walls; cells inclosed in a broad gelatinous sheath, in linear pairs, but

often evenly spaced; chloroplast an irregularly shaped, folded parietal plate which almost makes a complete cylinder within the wall, often showing a ridge or wing-like flange extending radially toward the wall; pyrenoid single, centrally located; cells 12–15 μ in diameter, 18–24 μ long.

In an acid swamp near Woodruff, Oneida County.

This species should be compared with *G. mutabilis* (de Bréb.) Wille from which it differs in the irregularly creased cell wall and the shape of the chloroplast. The determination of this plant has been confirmed by observation made on specimens discovered in collections from Cheboygan County, Michigan.

Hormidiopsis ellipsoideum sp. nov.

PL. 1, FIG. 9–10.

Cellulae transversim ellipticae, collocatae in seriebus linearibus in globis 4 cellulas continentes, quoque globo incluso vagina gelatinosa lata, hyalina homogeneaque; chloroplaste fascia parietali latitudine pari longitudine cellulae sed totum membranum non cingente, cum una pyrenoide; cellulis 8 μ lat., 5.5 μ long.; filo 14.8 μ lat.

Cells transversely elliptic, arranged in linear series in groups of four, each group inclosed by a wide, hyaline and homogeneous gelatinous sheath; chloroplast a parietal band as wide as the length of the cell but not entirely encircling the wall, with 1 pyrenoid; cells 8 μ in diameter, 5.5 μ long; filament 14.8 μ wide.

In a *Sphagnum* bog lake near Long Lake, Vilas County.

This plant appeared in but one collection. It is so distinctive that it seems worthy of description, however. *Hormidiopsis* is a little understood genus containing, apparently, but one other species, *H. crenulata* Heering. To this genus Heering has also questionably assigned a plant previously described by Borge as *Ulothrix moniliformis*. Our plant has the cell shape and approximate size of the latter, but differs in the arrangement of the cells. In *U. moniliformis* the cells have a continuous filamentous arrangement, inclosed by a sheath. All of the Wisconsin specimens had the cells arranged in crooked filaments in linear groups of four, each group with an individual sheath. Also in our specimens the chloroplast contained a pyrenoid, a character which is typical for the genus as described by Heering. This does not preclude our plants from the genus *Hormidiopsis* since it is one in which members of the Ulotrichaceae show considerable variation.

CHAETOPHORACEAE

Stigeoclonium pachydermum sp. nov.

PL. 2, FIG. 1–3.

Planta filum rectum ramosissimumque ex multis ramis rhizoidalibus deorsum eminentibus; ramis irregulariter dispositis et plurimum forma distantibus, plerumque alternis, sed cum uno ramo surgente protinus super alterum in latere adverso fili aut in plano rectis angulis posito, saepe evolvente ex cellulis brevibus et ligneo vaso similibus; multis ramis spinosis et deorsum irregulariter eminentibus evolventibus ex parte superiore axis principalis, qui rami in acumina obtusa fastigantur et saepe

finiuntur in cellulis aliquantum dilatatis, quadrangulato-globosis sporangialibusque quae et intercalares prope terminos ramorum brevium possunt esse; cellulis axis principalis 19.5–21 μ lat., ramorum 15–16 μ lat., cylindricis, etiam 20-plo longioribus diametro, aut brevibus et ligneo vaso similibus in eodem filo; membrano cellularum axis principalis 3–4 μ crass.

Plant an erect, much branched filament from numerous, downward projecting rhizoidal branches; branches irregularly disposed and extremely varied in form, mostly alternate, but with one branch arising immediately above another on the opposite side of the filament or in a plane at right angles to it, often developing from short, barrel-shaped cells; many thorn-like and irregular downward projecting branches developing from the upper part of the main axis, branches tapering to blunt points; frequently ending in somewhat enlarged, quadrangular-globose sporangial cells which may be intercalary near the ends of short branches also; cells in the main axis 19.5–21 μ wide, in the branches 15–16 μ wide, cylindrical and up to 20 times longer than wide, or short and barrel-shaped in the same filament; the wall of the cells in the main axis 3–4 μ thick.

In the shallow water of High Lake, Vilas County.

The chief characteristics of this plant are the irregularly arranged and crooked branches and the thick cell walls. In its coarse habit it resembles *S. lubricum* which is, however, a species with opposite branching. Rhizoidal types of branches appear both near the base of the plant and toward the apices of the main axes.

Draparnaldia Judayi sp. nov.

PL. 2, FIG. 4–5.

Planta mollissimo aquosoque glutine investita; axe principali composito ex cellulis gracilibus, paulo inflatis aut cylindricis cum constrictionibus in membrana transverso locatis; ramis secundariis lateralibus absentibus; fasciculis parvorum ramorum adversis aut tortis, surgentibus angulis rectis ex regione media cellularum axis, fasciculis paulum ramosis et cum rachide viso tantum in maioribus et bene formatis; fasciculis saepe simplicibus aut si ramosis habentibus ramulos unae aut duarum cellularum, apicibus plurimorum ramulorum finientibus in setis validis rectisque quae saepe bulbosae in basi sunt, nonnumquam surgunt ex latere aut dichotome divisae sunt; choloroplaste fascia maiorem partem membrani in cellulis ramulorum angusta in cellulis axis principalis quae sunt tegente; 12–15.2 μ lat., 30–40 μ long.

Entangled about overhanging grass in a *Sphagnum* bog pool near Rhinelander, Oneida County.

One of the most distinctive characteristics of this species is the whorled arrangement of the very simple and much reduced fascicles of branches, arising, as they do, from the midregion rather than from the joint of the main axial cell. The position of the branchlet origin is remindful of *Draparnaldiopsis alpinis* Smith and Klyver. In that species, however, the stalked fascicles arise from short, differentiated cells in the main filament. Another peculiarity is the form and location of the setae. These may be terminal, one or two arising from a non-tapering apical cell, or lateral, in which case they take the place of a dichotomous branch. The setae are similar in morphology to those of *Chaetonema*.

OEDOGONIACEAE

Oedogonium crenulatocostatum var. **cylindricum** fa. **major** fa. nov.

Forma maior quam ordinaria; cellulis vegetativis 25.9 μ lat., 88.8 μ long.; oogoniis 1–3, obovoideo-ellipsoideis aut cylindrico-oblongis, aperientibus poro superiore, 42.5–44 μ lat., 63–74 μ long.; oospora ovoideo-ellipsoidea, membrano crasso, strato medio cum circa 16 costis in longitudinem positis quae satis leves, non crenulatae sunt, 37–39 μ lat., 55.5–57 μ long.

A form larger than the typical; vegetative cells 25.9 μ in diameter, 88.8 μ long; oogonia 1–3, obovoid-ellipsoid or cylindric-oblong, opening by a superior pore, 42.5–44 μ in diameter, 63–74 μ long; oospore ovoid-ellipsoid, wall thick, middle layer with about 16 longitudinal ribs which are quite smooth (not crenulate), 37–39 μ in diameter, 55.5–57 μ long.

Floating in the back water of Lost Canoe Lake, Vilas County.

Our specimens are stouter and somewhat larger throughout than the typical variety.

Oedogonium Kjellmanii var. **granulosa** var. nov.

PL. 5, FIG. 1–3.

Cellulae vegetativae cylindricae, 19.5–23.4 μ lat., 109–117 μ long., oogonio solitario, ellipsoideo, superiore poro aperiente, 53–55 μ lat., 97–102 μ long.; oospora ellipsoidea, oogonium non replente, membrano tria strata habente, exterius leve, medium cum circa 22 costis in longitudinem positis quae crenulatae granulataeque, saepe interruptae, sed sine anastomose sunt, 50.7–53 μ lat., 74–76 μ long.

Vegetative cells cylindrical, 19.5–23.4 μ in diameter, 109–117 μ long, oogonium solitary, ellipsoid, opening by a superior pore, 53–55 μ in diameter, 97–102 μ long; oospore ellipsoid, not filling the oogonium, wall of three layers, the outer smooth, the middle layer with about 22 longitudinal ribs which are crenulate and granular, frequently interrupted, but not anastomosing, 50.7–53 μ in diameter, 74–76 μ long.

Attached to old wood in a roadside tarn near Boulder Junction, Vilas County.

This plant should be compared with *Oe. margaritiferum* Hirn which has similarly marked oospore walls in both the outer and middle layers. The variety differs from the typical form of *Oe. Kjellmanii* in its larger size and in the different marking of the spore wall.

Oedogonium oviforme var. **gracile** fa. nov.

PL. 5, FIG. 4–5.

Forma cum cellulis vegetativis gracilioribus et oogoniis minoribus quam in planta ordinaria; cellulis vegetativis 7.6–9.2 μ lat., 103.6–125 μ long.; oogonio solitario, ellipsoideo-ovoideo, 44.4–46 μ lat., 51.8–53 μ long.; oospora ellipsoidea, paene oogonium replente, membrano levi, 40.7 μ lat., 49.9 μ long.; cellulis antheridialibus 9.2 μ lat., 11.1 μ long.; spermatibus duobus, cum divisione horizontali.

A form with more slender vegetative cells and smaller oogonia than the typical plant; vegetative cells 7.6–9.2 μ in diameter, 103.6–125 μ long; oogonium solitary, ellipsoid-ovoid, 44.4–46 μ in diameter, 51.8–53 μ long; oospore ellipsoid, nearly filling the oogonium, wall smooth,

40.7 μ in diameter, 49.9 μ long; antheridial cells 9.2 μ in diameter, 11.1 μ long; sperms 2, division horizontal.

Attached to submerged aquatics in a slough cut off from Lost Canoe Lake, Vilas County.

Oedogonium Smithii sp. nov.

PL. 5, FIG. 6–7.

Macrandrosum; dioeciosum (?); cellulis vegetativis cylindricis aut irregulariter inflatis, 3.7–8 μ lat., 13–25 μ long.; oogonio solitario, late pyriformi-fusiformi cum inflatione laterali secondaria in parte superiore, operculato, cum divisione in medio, lato, 22–25 μ lat., 27–32 μ long.; oospora depresso-globosa, paene oogonium a latere replente, membrano levi, 16–18 μ lat., 12.9–14 μ long.; antheridio (?).

Macrandrous; dioecious (?); vegetative cells cylindrical or irregularly inflated, 3.7–8 μ in diameter, 13–25 μ long; oogonium solitary, broadly pyriform-fusiform with a secondary lateral inflation in the upper portion, operculate, division median, wide, 22–25 μ in diameter, 27–32 μ long; oospore depressed-globose, nearly filling the oogonium laterally, wall smooth, 16–18 μ in diameter, 12.9–14 μ long; antheridium (?).

Rare in a roadside pond near Genoa City, Washburn County. This plant is named for Dr. Gilbert M. Smith.

This species should be compared with *Oe. inconspicuum* Hirn. It is distinguished by the pyriform oogonium with its lateral inflations.

Oedogonium microgonium sp. nov.

PL. 5, FIG. 8.

Macrandrosum; dioeciosum (?); cellulis vegetativis clare capitellatis, 8–9.5 μ lat., 18–33 μ long.; in basi cellulis elongatis, 16–18 μ long.; oogonio solitario, rare cum duobus, sed paululo latiore quam cellulae vegetativae, globoso aut depresso-globoso, operculato, cum divisione superiore, 11–12.9 μ lat., 10–11.2 μ long.; oospora globosa, oogonium replente, membrano levi, 11–12 μ lat.; cellulis antheridialibus non observatis.

Macrandrous; dioecious (?); vegetative cells distinctly capitellate, 8–9.5 μ in diameter, 18–33 μ long; basal cell elongate, 16–18.5 μ long; oogonium solitary (rarely two together), but very little wider than the vegetative cells, globose or depressed-globose, operculate, division superior, 11–12.9 μ in diameter, 10–11.2 μ long; oospore globose, filling the oogonium, the wall smooth, 11–12 μ in diameter; antheridial cells not observed.

In several soft water lakes and acid swamps, Vilas County.

This species should be compared with *Oe. Howei* Tiffany which is larger and which has an inferior division of the oogonium. Although many individuals were examined antheridia were not found.

Oedogonium spheroideum sp. nov.

PL. 5, FIG. 9.

Macrandrosum; monoeciosum; cellulis vegetativis longis ac cylindricis, 16–19 μ lat., 115–155 μ long.; oogonio solitario, late ellipsoideo-subgloboso, operculato, cum divisione superiore, 55–64 μ lat., 80–87.5 μ long.; oospora spheroidali, membrano crasso, membrano exteriore cum 12–15 costis in longitudinem positis, 57–60 μ lat., 57–60 μ long.; cellulis antheridialibus 1–4, protinus infra oogonium locatis, aut sparsis, spermatibus 2, cum divisione horizontali, 19–21 μ lat., 16 μ long.

Macrandrous; monoecious; vegetative cells long and cylindrical 16–19 μ in diameter, 115–155 μ long; oogonium solitary, broadly ellipsoid to subglobose, operculate, division superior, 55–64 μ in diameter, 80–87.5 μ long; oospore spheroidal, the wall thick, outer membrane with 12–15 longitudinal ribs, 57–60 μ in diameter, 57–60 μ long; antheridial cells 1–4, immediately below the oogonium, or scattered, sperms two, the division horizontal, 19–21 μ in diameter, 16 μ long.

Attached to grass in a roadside swamp near Fishtrap Lake, Vilas County.

This species should be compared with *Oe. sol* Hirn which is smaller and has an oospore with the middle rather than the outer layer of the wall ribbed.

Oedogonium Sawyeri sp. nov.

PL. 5, FIG. 10.

Nanandrosum; gynandrosporosum; cellulis vegetativis cylindricis, validis, 30–33.3 μ lat., 66.6–81 μ long.; oogonio solitario, paene globoso, 63–66.6 μ lat., 55–60 μ long., aperiente poro superiore; cellula suffultoria inflata; oospora globosa, membrano exteriore cum claro iugo spirali, continuo a polo ad polum, axe sporae converso in angulo c. 30 graduum an axe oogonii in longitudine viso, 50–55 μ lat. (iugo incluso); plantis masculinis in cellula suffultoria locatus; cellulis antheridialibus 8–10 μ lat.; androsporangiis 25.9 μ lat., 14–18 μ long.

Nanandrous; gynandrosporous; vegetative cells cylindrical, stout, 30–33.3 μ in diameter, 66.6–81 μ long; oogonium solitary, nearly globose, 63–66.6 μ in diameter, 55–60 μ long, opening by a superior pore; suffultory cell swollen; oospore globose, outer membrane with a prominent spiral ridge, continuous from pole to pole, the axis of the spore turned at an angle of about 30 degrees from the longitudinal axis of the oogonium, 50–55 μ in diameter (including ridge); male plants on the suffultory cell; antheridial cells 8–10 μ in diameter; androsporangia 25.9 μ in diameter, 14.8 μ long.

In a cut-off from Lost Canoe Lake, Vilas County. This plant is named for Mr. Webster Sawyer.

Oe. Sawyeri should be compared with the smaller idioandrosporous *Oe. latviense* (Tiff.) Tiffany and *Oe. spiripennatum* Jao. The latter has a median rather than a superior pore.

Oedogonium sinuatum fa. **seriatum** fa. nov.

Cellulae vegetativae undulatae et capitellatae, cum 4 undulationibus in medio, 22–25 μ lat., 48–59.2–(140) μ long.; oogoniis 5 in seriebus, globosis, operculatis, cum divisione inferiore, 62–67 μ lat., 62–72 μ long.; oospora globosa, oogonium non replente, membrano levi, 55.5 μ lat.; plantis masculinis pusillis paene semper condensis in cellula suffultoria; cellulis antheridialibus exterioribus (?), 10.9 μ lat.

Vegetative cells undulate and capitellate, with 4 median undulations, 22–25 μ in diameter, 48–59.2–(140) μ long; oogonia five in series, globose, operculate, division inferior, 62–67 μ in diameter, 62–72 μ long; oospore globose, not filling the oogonium, wall smooth, 55.5 μ in diameter; dwarf male plants usually crowded on the suffultory cell; antheridial cells exterior (?), 10.9 μ in diameter.

Attached to overhanging grass in a Sphagnum bog ditch near highway between Woodruff and Rhinelander, Oneida County.

This plant should be compared with *Oe. undulatum* (Bréb.) A. Braun with which it has some features in common. The chief characteristic of the Wisconsin plants is the decidedly seriate arrangement of the oogonia.

Oedogonium Kozminskii sp. nov.

PL. 5, FIG. 11.

Nanandrosum; idioandrosporosum; cellulis vegetativis cylindricis vel paulo capitellatis, 14–15.6 μ lat., 50–60 μ long.; oogonio solitario, globoso, operculato, cum divisione supramediana, 46–50.7 μ lat., 46–53.7 μ long.; oospora globosa vel depresso-globosa membrano levi, 43.9–45 μ lat., 39–42 μ long.; cellula suffultoria haud dilatata vel paululo; plantis masculinis pusillis unicellularibus in oogonio locatis, 11.7 μ lat., 13–14 μ long.

Nanandrous; idioandrosporous; vegetative cells cylindrical to slightly capitellate, 14–15.6 μ in diameter, 50–60 μ long; oogonium solitary, globose, operculate, division supramedian, 46–50.7 μ in diameter, 46–53.7 μ long; oospore globose or depressed-globose, wall smooth, 43.9–45 μ in diameter, 39–42 μ long; suffultory cell not or scarcely enlarged; dwarf male plants unicellular, on the oogonium, 11.7 μ in diameter, 13–14 μ long.

Attached to grass in a bog near Arbor Vitae Lake, Vilas County. This plant is named for Dr. Zygmunt Kozminski.

This species is quite unlike any other in the genus. The shape and markings of the oospore together with the operculate oogonium and the numerous two-celled male plants, form a combination of characteristics which makes this species unique.

Oedogonium oelandicum var. **contortum** var. nov.

PL. 5, FIG. 13–14.

Varietas ordinaria differens in filis contortis quae nonnumquam breves spiras formant, multae quarum in uno filo possunt reperiri; cellulis vegetativis 11–12 μ lat., distincte capitellatis; oogonio multo breviore quam lat., depresso-globoso, 29–30 μ lat., 20–21.5 μ long.; oospora depresso-globosa, membrano levi, 25–27 μ lat., 18–20 μ long.; plantis masculinis pusillis unicellularibus in oogonio locatis.

A variety differing from the typical form by its contorted filaments which sometimes form short spirals, several of which may occur in one filament; vegetative cells 11–12 μ in diameter, distinctly capitulate; oogonium much shorter than wide, depressed-globose, 29–30 μ in diameter, 20–21.5 μ long; oospore depressed-globose, the wall smooth, 25–27 μ in diameter, 18–20 μ long; dwarf male plants unicellular, on the oogonium.

Attached to grass in a small lake near Barber Lake, Sawyer County.

Oedogonium polyandrium sp. nov.

PL. 5, FIG. 12.

Nanandrosum; idioandrosporum (?); cellulis vegetativis paulo capitellatis, 4–5.4 μ lat., 14–30 μ long.; oogonio solitario, ovoideo vel late ellipsoideo, operculato, cum apertura superiore, 17–19 μ lat., 27–29 μ long.; oospora ovoidea, oogonium paene replente, membrano exteriore sporae cum scrobiculationibus crassis sparsisque vel cum puteis brevibus, stratis medio et interiore membrani sporae levibus, 15–17 μ

lat., 22–25 μ long.; plantis masculinis pusillus bicellularibus, numerosis, in oogonio locatis, stipe 4.5 μ lat., 14–16 μ long.; cellula antheridiali exteriore (?).

Nanandrous; idioandrosporous (?); vegetative cells slightly capitellate, 4–5.4 μ in diameter, 14–30 μ long; oogonium solitary, ovoid or broadly ellipsoid, operculate, opening superior, 17–19 μ in diameter, 27–29 μ long; oospore ovoid, nearly filling the oogonium; outer spore wall with coarse, sparsely arranged scrobiculations or shallow pits, middle and inner layers of the spore wall smooth, 15–17 μ in diameter, 22–25 μ long; dwarf male plants two-celled, numerous, on the oogonium, stipe 4.5 μ in diameter, 14–16 μ long; antheridial cell exterior.

Attached to grass in a bog near Arbor Vitae Lake, Vilas County.

This species is quite unlike any other in the genus. The shape and markings of the oospore, together with the operculate oogonium and the numerous two-celled male plants form a combination of characteristics which makes this species unique.

HYDRODICTYACEAE

Pediastrum biradiatum var. **emarginatum** fa. **convexum** fa. nov.

PL. 2, FIG. 6.

Colonia perforata (clathrata), cellulis bilobatis in peripheria, lobis bifurcatis, margine interiore lobularum convexo; cellulis periphericis adiunctis tantum in parte inferiore marginum lateralium, lobis cellularum interiorum solummodo emarginatis; cellulis 11.7 μ lat., 9.7–10 μ long.; colonia 16 cellularum 44–50 μ lat.

Colony perforate (clathrate), cells bilobed at the periphery, the lobes bifurcate, the inner margin of the lobules convex; peripheral cells adjoined along the lower part of their lateral margins only, lobes of inner cells merely emarginate; cells 11.7 μ in diameter, 9.7–10 μ long; 16-celled colony 44–50 μ wide.

Rare in a *Sphagnum* bog near Woodruff, Oneida County.

Pediastrum muticum var. **crenulatum** var. nov.

PL. 2, FIG. 7.

Varietas ordinaria differens membranis crenulatis vel inaequaliter undulatis et in finitimis et in exterioribus superficiebus liberis locatis; colonia magna, cum etiam 134 cellulis (34–31–27–21–15–6); cellulis 18–24.5 μ lat., colonia 167 μ lat., 340 μ long.

A variety differing from the typical form by having crenulate or irregularly wavy walls on both the adjoining and outer free surfaces; colony large, as many as 134 cells (34–31–27–21–15–6); cells 18–24.5 μ in diameter, colony 167 μ wide, 340 μ long.

Rare in the plankton of Lost Canoe Lake, Vilas County.

Pediastrum quadricornutum sp. nov.

PL. 1, FIG. 11.

Colonia paene integra, cum parvissimis intersticibus formatis ex marginibus retusis nonnullarum cellularum; colonia oblonga, rare subcirculari (7–1) (16–11–5) (16–9–7), composita ex 8–32 cellulis alte bilobatis quae habent sinum altum angustumque formatem duas lobas maiores ita incisas ut fingant lobulas obtuse rotundatas, duae centrales quarum omnino aut paene coniunctae sunt, sic sinum extrinsecus claudentes,

duae lobulae laterales quarum tangunt lobulas laterales cellularum contiguarum; cellulis interioribus paene eiusdem formae quam cellulae periphericae sed cum lobulis minus prominentibus et nonnumquam absentibus, cum membrano tantummodo emarginato aut paene recto; cellulis 10.5–18 μ lat.; colonia 8 cellularum 154 μ lat.

Colony nearly entire, with minute interstices formed by the retuse margins of some cells; colony oblong, rarely subcircular (7–1) (16–11–5) (16–9–7), composed of 8–32 deeply bilobed cells which have a deep, narrow sinus forming two major lobes, the lobes incised to form bluntly-rounded lobules, the two central lobules in contact or nearly so, thus closing the sinus outwardly, the two lateral lobules in contact with the lateral lobules of the adjoining cells; interior cells about the same shape as the peripheral cells but with the lobules not so prominent, sometimes wanting, with the wall merely emarginate or nearly straight; cells 10.5–18 μ in diameter; eight-celled colony 154 μ wide.

Plankton in Beaver Lake and Trostel Lake, Vilas County.

According to Bigeard (1936) such a form as this would be included in *P. tetras* (Ehr.) Ralfs, a species which has many variations. The distinctive shape of the peripheral cells, and the narrow, closed sinus are constant characters and justify separating the Wisconsin plants from that species.

OOCYSTACEAE

Oocystis pyriformis sp. nov.

PL. 1, FIG. 12–13.

Cellulae late pyriformi-ovoideae, cum apiculatione conspicua uno polo, altero late rotundato; consociatae in familiis duarum vel quattuor cellularum; chloroplaste solida et parietali cum una pyrenoide; cellulis 14–16 μ lat., 16–19 μ long.; colonia 4 cellularum 36 μ lat., 48.8 μ long.

Cells broadly pyriform-ovoid, with a prominent apiculation at one pole, the other end broadly rounded; united in families of 2–4; chloroplast massive and parietal with one pyrenoid; cells 14–16 μ in diameter, 16–19 μ long; colony of four cells 36 μ in diameter, 48.8 μ long.

Plankton in cedar swamp near Antigo, Langlade County.

This species should be compared with *O. apiculata* W. West, a much smaller plant with broadly elliptic cells. The pyriform shape of the Wisconsin plants is the chief differentiating characteristic.

Tetraëdron asymmetricum sp. nov.

PL. 1, FIG. 14.

Cellula forma quadrangulata, incisa sine symmetria ita ut formet duas lobas maiores quae isthmum sinu late aperto praetectum habent; duae lobae maiores paulum bilobatae, lobulis 2–3 spinis brevibus praefixis; cellulae 10–18 μ in mensura longissima.

Cell quadrangular in outline, unsymmetrically incised to form two major lobes with an isthmus bordered by a widely open sinus, the two major lobes slightly bilobed, the lobules tipped with 2–3 short spines; cells 10–18 μ in their longest dimension.

Plankton in Big Clam Lake, Burnett County.

This species should be compared with *T. irregulare* (Reinsch) de Toni which it more nearly resembles than any other.

Tetraëdron bifurcatum var. **minor** var. nov.

PL. 1, FIG. 15.

Forma ab ordinaria differens in mensura minore et quod lobas bifurcatas habet, cum lobulis firmioribus et brevi spina praefixis; cellulae 22.5 μ in diametro maximo.

A form differing from the typical by its smaller size and in having the lobes bifurcated, the lobules rather stout and tipped with a short spine; cells 22.5 μ in their maximum diameter.

Plankton in Okauchee Lake, Waukesha County.

Tetraëdron cruciatum var. **reductum** var. nov.

PL. 1, FIG. 16.

Cellula plana, irregulariter cruciformis vel nonnumquam trilobata, lobis bifurcatus, lobulis brevi spina praefixis; margines cellulae in duobus lateribus oppositis concavi, in alteris lateribus recti aut tantum paululum concavi; cellulae 28–30 μ lat., etiam 54 μ in mensura longissima.

Cell flat, irregularly cruciform or sometimes three-lobed, the lobes bifurcate, the lobules tipped with a short spine; margins of the cell concave on two opposite sides, straight or only slightly concave on the other sides; cells 28–30 μ in diameter, up to 54 μ in the greatest dimension.

Plankton in Lost Canoe Lake and in Manitowish River, Vilas County.

This form differs from the typical in its broad, bilobed processes and in having the lateral walls much less concave or emarginate. It differs from var. *polyfurcatum* G. M. Smith in the form and number of processes.

Tetraëdron enorme var. **pentaëdricum** var nov.

PL. 1, FIG. 17.

Cellulae forma quinquelaterali, lateribus rectis vel paulo convexis, paribus processuum angustorum bifurcatorumque in omnibus planis extendentibus et brevibus spinis praefixis; cellulae 50–55 μ lat., processibus non inclusis.

Cells five-sided in outline, the sides straight or slightly convex, with pairs of narrow, bifurcated processes extending in all planes, the processes tipped with short spines; cells 50–55 μ in diameter without processes.

Rare in the plankton of Sweeney Lake, Vilas County.

This form differs from the typical plant in its straight margins and narrow, bifurcated processes extending from the angles. It is similar to Borge's figure of *T. enorme* (Ralfs) Hansgirg, which we judge to be atypical of that species.

Tetraëdron limneticum var. **gracile** var. nov.

PL. 1, FIG. 18.

Cellulae pyramidatae vel tetragonales, angulis in processus bifurcatos extentis qui 2–3 spinis firmis praefixi sunt; margines cellulae concavi inter processus; bases processuum contiguae ita ut corpus cellulae vix visibile sit; cellulae 40–46.8 μ lat., processus 6–8 μ lat.

Cells pyramidal, or tetragonal, the angles extended into bifurcate processes which are tipped with 2–3 stout spines, the margins of the cell concave between the processes; bases of the processes adjoining so that there is scarcely a cell body; cells 40–46.8 μ in diameter; processes 6–8 μ wide.

Plankton in Elcho Lake, Langlade County.

The processes of this form are so narrow and the cell body so greatly reduced that it approaches the genus *Treubaria.*

Tetraëdron lobulatum var. **crassum** var. nov.

PL. 2, FIG. 8.

Cellulae pyramidatae, tetragonales, angulis leviter productis ita ut forment processus comparate latos fortesque qui bilobati sunt, lobulis bifurcatis et in acuminibus brevibus, curvis, spinosisque finitis; cellulae 25–30 μ lat.

Cells pyramidal, tetragonal, the angles slightly produced to form relatively wide, stout processes which are bilobed, the lobules bifurcate and ending in short, curved, spine-like tips; cells 25–30 μ in diameter.

Plankton in Lost Canoe Lake and in Manitowish River, Vilas County.

Tetraëdron regulare var. **granulata** var. nov.

PL. 3, FIG. 1.

Cellulae magnae, pyramidatae, lobis latis fortibusque cum marginibus convexis instructis, angulis late rotundatis et spina solitaria brevique praefixis quae multo reducta esse potest adeo ut tantummodo papilla sit; membranum punctatum et parvis granulis aut asperitatibus copertum; cellulae 35–51.8 μ lat.

Cells large, pyramidal, the lobes broad and stout, with convex margins, the angles broadly rounded and tipped with a single short spine which may be reduced to a mere papilla; wall punctate and covered with small granules or roughenings; cells 35–51.8 μ in diameter.

Plankton in Flambeau Lake, Vilas County; Little Round Lake, Sawyer County.

Tetraëdron regulare var. **incus** fa. **major** fa. nov.

PL. 3, FIG. 2.

Cellulae pyramidatae, tetragonales marginibus rectis vel leviter convexis, angulis productis ut spinas longas fortesque forment; cellulae 35–50 μ lat. spinis inclusis; spinae 12–13.5 μ long.

Cells pyramidal, tetragonal, the margins straight or slightly convex, the angles produced to form long, stout spines; cells 35–50 μ in diameter including spines; spines 12–13.5 μ long.

Plankton from Sweeney Lake; in tow from Manitowish River, Vilas County.

SCENEDESMACEAE

Scenedesmus opoliensis var. **contacta** var. nov.

PL. 3, FIG. 3.

Planta constans ex 4 cellulis naviformibus in serie singula instructis, per ¾ longitudinem parietum lateralium coniunctis; spinis cellularum terminalium, 1 vel 2

utroque in polo, longius curvatisque; spinis cellularum interiorum brevibus rectisque, cellulis 6–8 μ diam., 20–24 μ long.

Plant consisting of four naviculoid cells arranged in a single series, adjoined along ¾ of the length of their lateral walls; spines on terminal cells either one or two at each pole, long and curved; spines on the inner cells short and straight; cells 6–8 μ in diameter, 20–24 μ long.

Plankton in Carpenter Lake, Vilas County.

Tetradesmus Smithii sp. nov.

PL. 3, FIG. 4–5.

Cellulae leviter arcuatae aut lunatae aut subcylindratae, parum coartatae in regione polorum qui sunt late rotundati, locatae in globis quattuor cellulas continentibus, axibus longis parallelis et membranis convexis adiunctis solum in regione media, membranis externis liberisque concavis aut paene rectis; cellulae a polo visae sphaericae, in quadrangula dispositae; chloroplastis lamina parietalis; cellulae 3.7–4 μ lat., 27–29 μ long.

Cells slightly arcuate or crescent-shaped or subcylindrical, slightly narrowed toward the poles which are broadly rounded, in groups of four with their long axes parallel and with the convex walls adjoined in the midregion only, outer free walls concave or nearly straight; cells in end view spherical, arranged in a quadrangle; chloroplast a parietal plate; cells 3.7–4 μ in diameter, 27–29 μ long.

Rare in the plankton of Devil's Lake, Burnett County. This species is named for Dr. Gilbert M. Smith.

Tetradesmus Smithii is very similar to some forms of *Quadrigula*, but the arrangement of the cells is very definite and the colonies are without a gelatinous sheath or envelope.

CONJUGALES

ZYGNEMATACEAE

Spirogyra pseudofloridana Prescott, n. sp.

TEXT FIG. 1.

Fila cellularum fortium cylindratarumque membrana plane finita habentium, 51–60 μ lat., 3–5-plo longioribus diametro; chloroplastes 4–(5) angustae, laxe spirales aut paene rectae, ½–1½ revolutiones in cellula facientes; coniugatio scalariformis facta per inclinationem geniculatum fili ita ut cellulae in iuxtapositione ponantur, gibbis lateralibus (sed non tubulis) nascentibus in cellulis gametangialibus quae breves et ut videtur cellulis vegetativis abscissae fiunt et graviter corporibus oleaceis inter coniugationem onustae sunt, cellulis fertilibus leviter tumidis; zygospora ellipsoidea cum polis anguste rotundatis, mesospora fulva atque granulationibus irregularibus et rugis (non reticulatis) asperata, 63–70 μ lat., 100–120 μ long.

Filaments of stout cylindrical cells with plane end walls, 51–60 μ in diameter, 3–5 times their diameter in length; chloroplasts 4–(5), narrow, loosely spiralled or nearly straight, making ½–1½ turns in the cell; conjugation scalariform by geniculate bending of the filament to bring the cells into juxtaposition, lateral bulges but not tubes forming on the gametangial cells which become shortened and apparently cut off from the vegetative cells, becoming heavily packed with oil bodies at the time

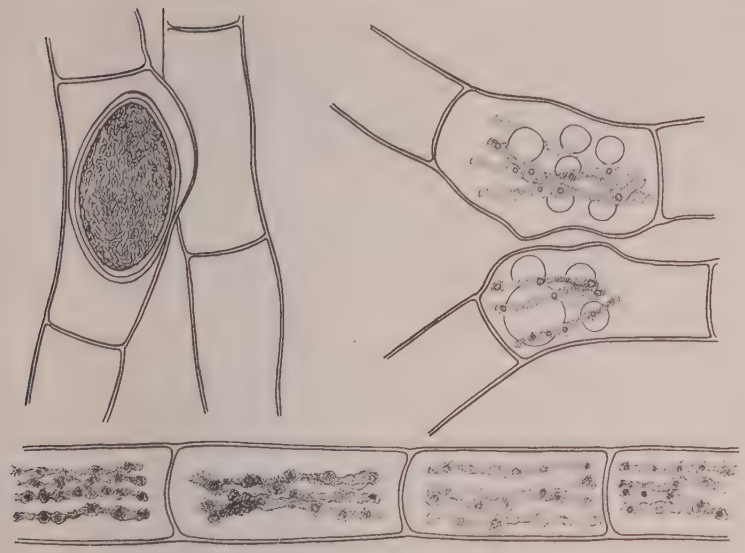

FIGURE 1. *Spirogyra pseudofloridana* Prescott n. sp. × 250.

of conjugation, the fertile cells becoming slightly swollen; zygospore ellipsoid with narrowly rounding poles, the mesospore brown and roughened with irregular granulations and wrinkles (not definitely reticulate), 63–70 μ in diameter, 100–120 μ long.

Floating clots in a lagoon-like cove, North Trout Lake, Vilas County.

This species should be compared with *S. illinoisensis* Transeau and *S. floridana* Transeau. It is smaller than the former and has fewer chloroplasts. From the latter it differs chiefly in the decoration of the mesospore layer of the zygospore wall.

PHYLUM CHRYSOPHYTA

A. XANTHOPHYCEAE

STIPITOCOCCACEAE

Stipitococcus apiculatus sp. nov.

PL. 3, FIG. 6–10.

Cellulae ovoideae vel fusiformes, apiculatae, stipite tenui coniunctoque instructae; chloroplastes 1–3; corpus oleaceum et filus rhizoidalis in apice locati; cellulae gregales, adiunctae turbinibus circum desmidibus filamentosis, nonnumquam 2 vel 3 cellulis in serie in una stirpe locatis, protoplastibus filamentis rhizoidalibus connexis; cellulae 3.8–4 μ lat., 18–36 μ long., stipe incluso.

Cells ovoid or fusiform, apiculate, with a slender attaching stipe; chloroplasts 1–3; an oil body and a rhizoidal thread at the apex; cells gregarious, attached in whorls about filamentous desmids, sometimes two or three cells in a series on one stalk, the protoplasts connected by rhizoidal threads; cells 3.8–4 μ in diameter, 18–36 μ long including the stipe.

On *Hyalotheca* filaments; pond near Silver Lake, Langlade County.

The arrangement of the cells in dense, transverse zones about the host filament gives a very distinct appearance to this species. The occurrence of two or three cells in a series on a single attaching stipe is unlike any of the described species. It is thought that this condition must be the result of *in situ* germination of swarmers.

Stipitococcus crassistipatus sp. nov.

PL. 3, FIG. 11–14.

Cellula late (nonnumquam anguste) in forma ampulla figurata, coartata in parte anteriore in collum breve latumque et reductum in parte posteriore in stipitem crassum et 1.5–2 μ lat.; protoplastis ovalis vel subglobosa, 2 chloroplastibus laminatis instructa; 7.6–8 μ lat., 18–20 μ long.

Cell broadly (sometimes narrowly) flask-shaped, narrowed anteriorly into a short, broad neck and reduced posteriorly to a thick stipe, 1.5–2 μ wide; protoplast oval to subglobose, with two laminate chloroplasts; 7.6–8 μ in diameter, 18–20 μ long.

On filamentous algae in a pool on beach of Crystal Lake, Vilas County.

This species differs in having a stipe which is much stouter and less tapering than in the other described forms. It should be compared with *St. capense* Prescott which has a very similarly shaped lorica but a very slender, tapering stipe. Also compare with *Derepyxis amphora* Stokes which it superficially resembles.

OPHIOCYTIACEAE

Ophiocytium desertum var. **minor** var. nov.

PL. 3, FIG. 15–16.

Cellulae coniunctae, cylindratae aut in forma farciminis figuratae, stipite basis habente partem connexa, planatam similemque disco, polo anteriore late rotundato, 4–9 μ lat., 58–65 μ long.

Cells attached, cylindrical or sausage-shaped, basal stipe with a flattened disc-like attaching organ, anterior end broadly rounded, 4–9 μ in diameter, 58–65 μ long.

In a roadside swamp near Boulder Junction, Vilas County.

This variety differs from the typical form only in its distinctly smaller size.

Ophiocytium elongatum var. **major** var. nov.

PL. 3, FIG. 17.

Varietas ordinaria differens in mensura multo maiore; cellulae libere natantes, cylindricae, rectae, curvae, aut uno polo truncato hamatae, altero spinam fortem, non undulatam, habente; chloroplastes 16 disci parietales; cellula 10–12 μ lat., 400–420 μ long., stipe (10–12 μ long.) non incluso.

A variety differing from the typical by its much greater size; cells free-floating, cylindrical, straight, curved or hooked at one end which is truncate, the other bearing a stout spine, not coiled; chloroplasts 16 parietal discs; cell 10–12 μ in diameter, 400–500 μ long without the stipe which is 10–12 μ long.

In a swamp near Rhinelander, Oneida County.

This variety should be compared with *O. cochleare* (Eich.) A. Braun which differs in its smaller size, arcuate or coiled cells. *O. elongatum* W. & G. S. West, originally described from Burma, is sometimes coiled, although not closely, and its dimensions are greater than for any of the other species in this genus. Our specimens are mostly curved or bent near one end and are not coiled.

B. CHRYSOPHYCEAE

MALLOMONADACEAE

Mallomonas pseudocoronata sp. nov.

PL. 3, FIG. 18.

Cellulae fusiformi-ellipticae, anguste rotundatae ambobus polis; squamae transverse elliptico-rhomboidales aut scutulatae, non imbricatae, in seriebus spiralibus transversisque positae; in polo anteriore formantes coronam proiecturarum acute praefixarum circum aperturam flagelli; acus duorum geberum, alterae fortes longaeque formantes floccum posteriorem, alterae breves spinosaeque, recurvatae super superficiem; cellulae 20–25 μ lat., 48–50 μ long., acibus inclusis.

Cells fusiform-elliptic, narrowly rounded at both poles; scales transversely elliptic to rhomboidal or diamond-shaped, not imbricate, in spiral transverse series; at the anterior end forming a corona of sharply pointed projections about the flagellum opening, needles of two kinds, stout long ones forming a posterior tuft, and short spine-like recurved ones over the surface; cell 20–25 μ in diameter, 48–50 μ long including the needles.

Plankton in Lake McKenzie, Burnett County.

The collar or 'crown' at the anterior end which is formed of spine-like scales, together with the shape and arrangement of the needles in the posterior region differentiate this species.

Mallomonas urnaformis sp. nov.

PL. 3, FIG. 19.

Cellulae ellipticae et coronam collumve squamarum erectarum in polo anteriore circum foramen flagelli habentes, squamis membrani rectangularibus in seriebus transversis longitudinalibusque positis; squamae paucae immutataeque in polo posteriore locatae; acus paucae, longae, tenuesque, passim divertentes, aequaliter sparsae; cellulae 11–14 μ lat., 25–30 μ long., acibus non inclusis.

Cells elliptic with a corona or neck of erect scales at the anterior end about the flagellum pore, scales of the membrane rectangular in transverse and longitudinal series and with a few modified scales at the posterior end; needles few, long and slender, diverging in all directions, evenly scattered; cells 11–14 μ in diameter, 25–30 μ long, without needles.

Tow from Boulder Lake, Vilas County.

The arrangement of the rectangular scales in regular transverse series is unique in this species.

RHIZOCHRYSIDACEAE

Lagynion reductum sp. nov.

PL. 3, FIG. 20–21.

Lorica globoso-conica, fusco-fulva, habens, aperturam densatione anulari circumdatam per quam extendit filus tenuis protoplasmatos; protoplastus globosus; chromatophorus unus, in uno latere cellulae positus; 10 μ alt., 11.5 μ lat.

Lorica globose to conical, dark brown, with an opening surrounded by an annular thickening through which a fine protoplasmic thread extends; protoplast globose; chromatophore one, laying along one side of the cell; 10 μ high, 11.5 μ in diameter.

Growing on filaments of *Tribonema* in a ditch near Rhinelander, Oneida County.

This organism is remindful of *Heterolagynion Oedogonii* Pascher (Ber. Deutsche Bot. Ges., **30**: 157, figs. 1–4, 7–9. 1912) which is, however, colorless and much larger than our species.

Lagynion triangularis var. **pyramidatum** var. nov.

PL. 3, FIG. 22.

Lorica anguste pyramidata, marginibus inaequalibus aut subtriangularibus, fastigata in collum breve longumve marginibus fere parallelis instructum; 10.8–12 μ lat., 15–20 μ alt.

Lorica narrowly pyramidate with uneven margins, or subtriangular, tapering to a short or long neck with nearly parallel margins; 10.8–12 μ wide, 15–20 μ high.

On filamentous algae in Cardinal Bog, Trout Lake, Vilas County.

This variety differs from the typical form in being narrower, proportionately taller and in having a longer neck.

PHYLUM EUGLENOPHYTA

EUGLENACEAE

Euglena breviflagellum Prescott and Gojdics sp. nov.

PL. 3, FIG. 23–24.

Cellulae leviter metabolicae, elongato-fusiformes et spiraliter tortae curvataeve, raro rectae ellipticae in transverso visae, nonnihil coartatae in parte anteriore et truncatae, in parte posteriore coartatae lenius ita ut caudum longum forment; membranum subtiliter spiraliterque striatum; flagellum breve, in mensura par sextae parti longitudinis cellulae; paramyla corpora duarum varietatum, 6–8 laminae magnae concavae alveataeve a latere dispositae et axi longo parallelae, pellicula leviter undulata supra et aliis anulis discis similibus numerosis et parvis irregulariter per cellulam sparsis; chloroplastes disci numerosi ovoideique regulariter per cellulam dispositi; pyrenoides nullae; macula ocularis elliptica, formata ex granulis coccineis irregulariter locatis; cellulae 120–145 μ long., 10–12 μ lat.; corpora paramyla magna 18 μ long.; grana paramyla parva 5 μ lat., 7 μ long.

Cells slightly metabolic, elongate-fusiform and spirally twisted or curved, seldom straight, elliptic in cross section, rather abruptly narrowed anteriorly and truncate, posteriorly narrowing more gradually to form a long caudus; membrane finely and spirally striate; flagellum short, about one-sixth of the length of the cell; paramylon bodies of two sorts, 6–8 large concave or trough-shaped plates laterally arranged and parallel with the long axis with the pellicle slightly undulate over them, and other

numerous and small disc-like rings irregularly scattered throughout the cell; chloroplasts numerous ovoid discs evenly distributed throughout the cell; pyrenoids lacking (?); eye-spot elliptic, composed of irregularly arranged crimson granules; cells 120–145 μ long, 10–12 μ in diameter; large paramylon bodies 18 μ long; small paramylon grains 5 μ wide, 7 μ long.

Tychoplankton in Trilby Lake, Vilas County; also found in a pond near Woods Hole, Massachusetts, August, 1935 (Gojdics).

The plate-like and laterally arranged paramylon bodies are distinctive. The organism continually twists and turns in its movements and in so doing causes the paramylon plates to telescope or overlap.

Euglena elastica sp. nov.

PL. 3, FIG. 25–27.

Cellulae maxime metabolicae et in statu natandi formam constanter mutantes, maxima ex parte fusiformes, saepe, autem, media in parte inflatissimae atque postice anticeque abrupte coartatae, ad apices conice rotundatos paululum attenuatae; saepe, autem, parte basali inflatissima nodiformique, in caudum numquam extensa; flagello circa ⅔ longitudinem cellulae habente; chloroplastis multis, irregulariter ovatis; sine pyrenoidis (?); paramyli granis bacillis multis brevibusque, per cellulam quasi aequaliter dispersis; stigmate irregulari atque parte in anteriore cellulae laterali; cellulis 9.5–11 μ diam. (cellula videlicet extensa), 76–100 μ long.

Cells highly metabolic and constantly changing shape when in motion, mostly spindle-shaped but frequently much swollen in the midregion and abruptly narrowed anteriorly and posteriorly, tapering slightly to conically rounded apices, but often with the basal end much swollen and knob-like, never extended into a caudus; flagellum about ⅔ the length of the cell; chloroplasts many, irregularly ovoid bodies; pyrenoids lacking (?); paramylon bodies numerous short rods scattered rather evenly throughout the cell; pigment-spot an irregularly shaped body, lateral in the anterior end; cells 9.5–11 μ in diameter (when the cell is stretched out), 76–100 μ long.

In a small pool near Plum Creek at Sayner Fish Hatchery, Oneida County.

Euglena minuta sp. nov.

PL. 3, FIG. 28–30.

Cellulae maxime metabolicae, fusiformes ad subpyriformes; postice in cacumen breve, obtusum, saepe curvatum productae; membrana levi (?); flagello ¾ longitudinem cellulae habente; chloroplasto uno, laminiformi, pyrenoidum habente; paramyli granis bacillis multis parvisque aut granulis elongato-ovatis; cellula 5–6 μ diam., 12–13.5 μ long.

Cells highly metabolic, fusiform to somewhat pyriform; produced posteriorly into a short, blunt, often curved tip; membrane smooth (?); flagellum ¾ the length of the cell; one plate-like chloroplast with a pyrenoid; paramylon bodies many small rods or elongate-ovoid grains; cells 5–6 μ in diameter, 12–13.5 μ long.

Tychoplankton in Muskellunge Lake, Vilas County.

This is the smallest species of the genus recorded in North America. The highly metabolic cells with a single chloroplast and small rod-like

paramylon bodies make this organism different from other described species.

Euglena oxyuris var. **minor** var. nov.

PL. 3, FIG. 31.

Cellulae paulum metabolicae in statu natando formam constantem saepissime retinentes, elongato-cylindricae tortaeque, postice ad caudem brevem efficiendam quasi abrupte attenuatae; periplasto longitudinaliter striato; chloroplastis multis, disciformibus; paramyli granis 2 anulis magnis complanatisque, uno anteriore uno posteriore quam nucleo centrali; cellulis 15–18 μ diam., 77–85 μ long.

Cells slightly metabolic, mostly keeping a constant shape in movements, elongate-cylindric and twisted, tapering posteriorly rather abruptly to form a short tail piece; periplast longitudinally striated; chloroplasts numerous, disc-like; paramylon grains as two large, flattened rings, one anterior and one posterior to the central nucleus; cells 15–18 μ in diameter, 77–85 μ long.

In shallow water of High Lake, Vilas County.

This variety differs from the typical form by its smaller size, the latter being twice as large (30–45 μ in diameter, 375–490 μ long).

Phacus anacoelus var. **undulata** fa. **major** fa. nov.

PL. 4, FIG. 1.

Cellulae late ovoideae, finientes in parte posteriore in caudo longo et oblique directo; margines cellulae ruga alta in ambobus lateribus posita instructi quae duos gibbos latos format; multo maior quam forma ordinaria; 64 μ lat., 111–115 μ long.

Cells broadly ovoid, ending posteriorly in a long, obliquely directed caudus; margins of cell with a deep crease on either side forming two broad bulges; much larger than in the typical form, 64 μ in diameter, 111–115 μ long.

Plankton in Spider Lake, Vilas County.

This variety is very similar in size and shape to the typical form but is differentiated by the prominent lateral creases or incisions which throw the margin into broad undulations.

Phacus asymmetrica sp. nov.

PL. 3, FIG. 32.

Cellula irregulariter ovoideo-fusiformis et leviter spiralis in partibus anteriore et posteriore; extenta in parte posteriore in caudum curvatum obtuseque praeacutum; coartata in parte anteriore et habens duos gibbos inaequales in ambobus lateribus apicis positos; periplastis subtiliter per longitudinem striata; corpora paramyla duo anuli crassi torsique, plerumque per transversum cellulae locati; chloroplastes disci ovoidei numerosi parvique; cellula 22–25 μ lat., 50–53 μ long.

Cell irregularly ovoid-fusiform and slightly spiral in the posterior and anterior portions; extended posteriorly into a curved, bluntly pointed caudus; narrowed anteriorly and with two irregular bulges on either side of the apex; periplast finely striated longitudinally; paramylon bodies as two thick twisted rings, usually lying transversely in the cell; chloroplasts numerous small ovoid discs; cell 22–25 μ in diameter, 50–53 μ long.

In a roadside fosse near Shell Lake, Washburn County.

This species should be compared with *P. Raciborski* Drez. which is much more slender and more nearly symmetrical. *P. asymmetrica* is irregular in outline and in some instances seems more like an *Euglena*. The cells are flattened, however, and show periplast features and paramylon grains which are like *Phacus*, especially in regard to the arrangement of the latter. Besides the two large rings of paramylon there are numerous smaller bodies which sometimes are densely packed in the cell.

Phacus Birgei sp. nov.

PL. 3, FIG. 33.

Cellula late ovalis, producta in parte posteriore ut formet caudum longum fastigatumque qui obliquus axi longitidinali cellulae est, late rotundata in parte anteriore; flagellum in longitudine cellulae par; periplast tenuissime striata; margines cellulae acute incisae quattuor incisuris utrimque positis; corpora paramyla una magna et numerosae parvae laminae circulares; chloroplastes multi disci ovoidei; macula ocularis (?); cellulae 50–60 μ lat., 70–80 μ long.

Cell broadly oval, produced posteriorly to form a long tapering caudus which is oblique to the longitudinal axis of the cell, broadly rounded anteriorly; flagellum as long as the cell; periplast very finely striated; margins of the cell sharply notched with four small indentations on either side; paramylon bodies one large and numerous small circular plates; chloroplasts many ovoid discs; eye-spot (?); cells 50–60 μ in diameter, 70–80 μ long.

In a small pond near Genoa City, Walworth County. This species is named for Dr. E. A. Birge.

The lateral creases, together with the shape and size of this species, present a combination of characteristics which separate it from other described *Phacus*.

Phacus chloroplastes sp. nov.

PL. 3, FIG. 34.

Cellulae late pyriformes; productae in parte posteriore ut caudum rectum vel levissime deflexum forment; late rotundatae in parte anteriore cum papilla in medio posita; periplastis per longitudinem striata; margo cellulae integer; chloroplastes aliquot ligamenta parietalia quae parallela axi longo cellulae sunt; corpora paramyla duo magni tenuesque anuli aut laminae leviter torsae quae per longitudinem cellulae positae sunt; macula ocularis in medio regionis apicalis locata; cellula 20–22 μ lat., 29–31 μ long.

Cells broadly pyriform; produced posteriorly to form a straight or very slightly deflected caudus; broadly rounded anteriorly with a median papilla; periplast longitudinally striated; margin of the cell entire; chloroplasts several parietal bands lying parallel with the long axis of the cell; paramylon bodies two large, thin rings or slightly twisted plates lying lengthwise in the cell; eye-spot median in the apical region; cell 20–22 μ in diameter, 29–31 μ long.

Plankton in an inlet to Trout Lake, Vilas County.

This species should be compared with *P. hispidula* (Eich.) Lemm. which it resembles in general shape. The distinctive features of the Wisconsin

species are the shape and the arrangement of the chloroplasts which are quite unlike any of the other described members of the genus.

Phacus chloroplastes fa. **incisa** fa. nov.

PL. 4, FIG. 2–4.

Cellulae pyriformes vel napiformes in lineis extremis visae, fastigatae repente in longum caudum rectum acutumque; periplastis per longitudinem striata; margo cellulae instructus duabus incisuris utrimque locatis; cellulae 25–26 μ lat., 38–40 μ long.

Cells pyriform or napiform in outline, tapering suddenly to a long, straight, sharp caudus; periplast longitudinally striated; margin of the cell with two sharp notches on either side; cells 25–26 μ in diameter, 38–40 μ long.

In a cedar swamp, Lincoln County.

Phacus crenulata sp. nov.

PL. 4, FIG. 5.

Cellula ovoideo-pyriformis, extenta in parte posteriore ut formet caudum leviter fastigatum et acute praefixum; para anterior late rotundata sed bilobata cum papilla convexa inter lobas posita; flagellum par cellulae in longitudine aut paulo longius; margines cellulae distincte crenulati aut undulati; periplastis per longitudinem lineis undulatis striata; corpora paramyla duo disci circulares; cellulae 14–15 μ lat., 34–36 μ long.

Cell ovoid-pyriform, posteriorly extended to form a gradually tapering, sharp-pointed caudus, anterior end broadly rounded but bilobed with a convex papilla between the lobes; flagellum as long as the cell or a little longer; margins of the cell distinctly crenulate or undulate; periplast longitudinally striated with undulating lines; paramylon bodies as two circular discs; cells 14–15 μ in diameter, 34–36 μ long.

Plankton in a cedar swamp, Lincoln County.

This species should be compared with *P. costata* Conrad which has spiral, entire striations rather than longitudinal wavy ones. The anterior end is different in that species also. *P. setosa* var. *crenata* Skv. has spiral striations.

Phacus pseudoswirenko sp. nov.

PL. 4, FIG. 8.

Cellulae orbiculares in lineis extremis visae, repente coartatae in parte posteriore et productae ut forment caudum brevum acutumque qui ad sinistrum curvatur; pars anterior late rotundata; flagellum in longitudinem corpori fere par; periplastis per longitudinem striata, incisura laterali alta acutaque in medio lateris dextri posita (rare una etiam in latere sinistro); corpus paramylon lamina magna circularisque; cellulae 30–33 μ lat., 37–40 μ long.

Cells orbicular in outline, abruptly narrowed posteriorly and produced to form a short, sharp caudus which curves to the left; anterior end broadly rounded; flagellum about as long as the body; periplast longitudinally striated, with a deep, sharp, lateral notch medianly located on the right side (rarely one on the left side also); paramylon body a large circular plate; cells 30–33 μ in diameter, 37–40 μ long.

Plankton in a cedar swamp, Lincoln County, and in several ditches and small ponds.

This species should be compared with *P. Swirenko* Skvortz., a form which is about the same size but which has entire margins and a caudus which turns to the right.

Phacus Segreti var. **ovum** var. nov.

PL. 4, FIG. 9.

Cellulae maiores quam in species ordinaria late ovoideae atque rotundatae in partibus et anteriore et posteriore, caudo carentes; periplastis per longitudinem striata; corpora paramyla duo disci anulares; cellulae 28–30 μ lat., 39–41 μ long.

Cells larger than in the typical form, broadly ovoid and rounded both posteriorly and anteriorly, without a caudus; periplast longitudinally striated; paramylon bodies two annular discs; cells 28–30 μ in diameter, 39–41 μ long.

In a swamp near Lauderdale Lakes, Walworth County.

Phacus spirogyra var. **maxima** var. nov.

PL. 4, FIG. 6–7.

Cellulae ovoideae vel quasi-oblongae, inaequaliter spirales aut tantummodo torsae, repente coartatae in parte posteriore in longum caudum rectum curvumve; late rotundatae in parte anteriore (anguste rotundatae a latere visae), cum gibbo claro in medio posito; periplastis per longitudinem seriebus spiralibus granulorum gemmeorum striata; chloroplastes disci numerosi; corpora paramyla duo anuli magni ellipticique; cellulae 35–40 μ lat., 70–80 μ long.

Cells ovoid to somewhat oblong, unsymmetrically spiral or merely twisted, abruptly narrowed posteriorly into a long straight or curved caudus; broadly rounded anteriorly (narrowly rounded when seen from the side), with a prominent median protrusion; periplast longitudinally striated with spiral rows of pearly granules; chloroplasts numerous discs; paramylon bodies two large doughnut-like rings; cells 35–40 μ in diameter, 70–80 μ long.

In a roadside fosse near Shell Lake, Washburn County.

This variety is peculiar in the shape of the body which is not very much flattened. In side view it is narrower, however, than when seen in front view. The form of the paramylon bodies and the periplast decorations are similar to those in *Euglena spirogyra* var. *marchica*. This type of periplast decoration is uncommon in the genus *Phacus*. While most specimens had but two large paramylon rings some individuals were found with three. The cell is irregularly twisted in the anterior end. This species should be compared with *P. striata* France.

Drezepolski's description of *P. spirogyra* is not entirely complete and since it has been impossible to see type specimens of that species, the Wisconsin forms are assigned here with a question.

Lepocinclis glabra fa. **minor** fa. nov.

PL. 4, FIG. 10.

Cellulae late ovoideae, caudo brevi papillaeque simili instructae, late rotundatae in parte anteriore et finientes in gibbo bipapillato per quem emergit flagellum; flagellum in longitudine fere corpori par; periplastis levis; paramylon ex duobus ligamentis semicircularibus compositum, curvatis in transverso in peripheria cellulae, uno utrimque locato; chloroplastes numerosi disci ovales; cellulae 14–16 μ lat., 20–22 μ long., minores quam in forma ordinaria.

Cells broadly ovoid, with a short papilla-like caudus, broadly rounded anteriorly and ending in a bi-papillate protrusion through which the flagellum emerges; flagellum about as long as the body; periplast smooth; paramylon in the form of two semicircular bands, curving transversely at the periphery of the cell, one on either side; chloroplasts numerous, ovoid discs; cells 14–16 μ in diameter, 20–22 μ long, smaller than the typical form.

Tow sample from a cedar swamp in Lincoln County.

Trachelomonas hexangulata var. **repanda** var. nov.

PL. 4, FIG. 11.

Distans a specie ordinaria in marginibus lateralibus loricae convexioribus et marginibus lateralibus partis posterioris concavioribus adeo ut apiculatio obtusa in parte posteriore proferatur; lorica 14.4–15 μ lat., 36–38 μ long.

Differing from the typical form in having the lateral margins of the test more convex and the posterior lateral margins more concave so that a blunt apiculation is produced posteriorly; test 14.4–15 μ in diameter, 36–38 μ long.

In tow samples from a cedar swamp in Lincoln County.

Trachelomonas mammillosa sp. nov.

PL. 4, FIG. 12.

Testa spherica; ore flagelli in inflatione mammillata, per costam cincta crassa, anularemque, quae extremitatem, anteriorem circumplectitur; membrana levi, subflava; testa 24–26 μ diam.

Test spherical; flagellum aperture in a mammillate swelling which is surrounded by a thick annular ridge encircling the anterior end; wall smooth, yellowish; test 24–26 μ in diameter.

Tychoplankton in Stevens Swamp near Trout Lake, Vilas County.

This species is distinguished by the prominent ridge which encircles the test anteriorly, and the papillate swelling about the flagellum aperture. It should be compared with *T. peridiniformis* Skv. reported from Manchuria.

Trachelomonas superba var. **spinosa** var. nov.

PL. 4, FIG. 13.

Lorica late ovalis; membranum spinosum, parte posteriore spinis multo longioribus et acutius praefixis cincta; apertura flagelli torque carens sed coronula spinarum acutarum erectarumque circumdata; lorica 32.5–36 μ lat., 39–48 μ long.

Test broadly oval; wall spiny, with the posterior part beset with much longer and more sharply pointed spines; flagellum aperture without a

collar but encircled with a coronula of sharp, erect spines; test 32.5–36 μ in diameter, 39–48 μ long.

Plankton from Muskellunge Lake, Vilas County.

This variety differs from the typical form by the longer spines at the posterior pole and the coronula about the flagellum aperture. Also the size is greater in the variety.

PHYLUM PYRROPHYTA

GYMNODINIALES

GYMNODINIACEAE

Gymnodinium caudatum sp. nov.

PL. 4, FIG. 14–16.

Cellulae magnae, ovoideae aut inverse conicae aut similes turbini in forma, late rotundatae in polo anteriore, coartatae et productae in caudum curvum in polo posteriore; plurimum complanatae in parte dorso-ventrali; sulcus transversus clarus in medio positus, spiraliter ad sinistrum versus; chromatophori numerosae et luteo-fulvae laminae, ovoideae elongataeve, radialiter dispositae; macula ocularis prope sulcum in hypocono posita; sulcus per dimidiam longitudinem hypoconi extendens et paulum in epiconum; cellula 65–70 μ lat., 104–118 μ long.

Cells large, ovoid to inversely conical or top-shaped, broadly rounded at the anterior end, narrowed and produced into a curved caudus at the posterior pole; very much flattened dorso-ventrally; transverse furrow prominent and median, spirally turned to the left; chromatophores numerous golden-brown, ovoid or elongate plates, radially disposed; eye-spot present near the sulcus in the hypocone; longitudinal furrow extending about half the length of the hypocone and for a short distance into the epicone; cell 65–70 μ in diameter, 104–118 μ long.

In a *Sphagnum* bog near Rhinelander, Oneida County.

The large size of this species and the narrowed hypocone which forms a distinct caudus posteriorly are its distinguishing features.

PHYLUM CYANOPHYTA

CHROOCOCCALES

CHROOCOCCACEAE

Glaucocystis duplex sp. nov.

PL. 4, FIG. 17–19.

Colonia 8–16 cellularum sphaericarum membrano sphaerico cellulae matricalis multo dilatato circumdata; chromatophori duae massae stellatae habentes corpora vermiformia et caeruleo-viridia ex duobus locis separatis extendentia; cellulae 40–44 μ lat., colonia 150–170 μ lat.

Colony of 8–16 spherical cells inclosed by a much enlarged spherical mother-cell wall; chromatophores two stellate masses with vermiform, blue-green bodies radiating from two separate points; cells 40–44 μ in diameter, colony 150–170 μ in diameter.

Among dense clots of algae in Manitowish River, Vilas County.

This species differs from *G. nostochinearum* Itz. in the spherical shape of the cell and in the dual arrangement of the chromatophores. From *G. cingulata* Bohlin it differs in the morphology of the cell wall. That species is spherical but the wall has a median annular thickening. The chromatophores are numerous and parietal. Some forms of *G. nostochinearum* Itz. are described as spherical but other features of the Wisconsin plants seem to warrant separating them from that species.

Glaucocystis oocystiformis sp. nov.

PL. 4, FIG. 20.

Cellulae solitariae (aut in coloniis positae ?) late ellipticae, densationibus glandulosis membrani in polis instructae; chromatophori numerosi, pulvinaribus in peripheria cellulae circum vacuolam centralem, sphaericum, non coloratam positis (?); cellulae 20–27.3 μ lat., 40–45 μ long.

Cells solitary (or in colonies ?) broadly elliptic, with nodular thickenings of the cell wall at the poles; chromatophores numerous, irregular pads at the periphery of the cell about a central, spherical, colorless vacuole (?); cell 20–27.3 μ in diameter, 40–45 μ long.

Plankton from an inlet to Trout Lake, Vilas County.

This species differs from the others in the shape of the cell, the form of the chromatophores, and in its possession of polar nodules. Whether the absence of colonial association, or the retention of autospores within the mother-cell wall is a constant feature is undetermined, but in all cases observed the cells were solitary. In the developmental stages of *G. nostochinearum* Itz., as described by Hieronymus (1892), the chromatophores show much the same character as exhibited in *G. oocystiformis*. Since no other type of chromatophore expression or arrangement was found in the Wisconsin plants there is no indication that the forms in our collections are but a developmental stage of some other species.

HORMOGONALES

OSCILLATORIACEAE

Lyngbya latissima sp. nov.

PL. 4, FIG. 21.

Plantae solitariae, in aliis algis impeditae; trichomata recta, in apicibus non fastigata; cellulae discis similes materiam tenuiter aequaliterque granosam habentes, 37–40 μ lat., 3.7–7.4 μ long.; vagina dense (3.7–5 μ), lamellata, stratis externis rugosis et senectute asperatis; filamentum 44–58 μ lat.

Plants solitary, entangled among other algae; trichomes straight, not tapering at the apices; cells disc-like with contents finely and evenly granular, 37–40.7 μ in diameter, 3.7–7.4 μ long; sheath thick (3.7–5 μ), lamellate, with outer layers wrinkled and roughened in age; filament 44–58 μ in diameter.

In Sweeney Lake, Vilas County; Little Clam Lake, Burnett County.

This very large species should be compared with *Oscillatoria princeps* Vauch. when the latter is in the hormogonial condition and inclosed by

a sheath. In such a case the sheath is not thick and lamellated as in *L. latissima,* nor are the trichomes so long (usually). *L. gigantea* described by Lewis, Zirkle, and Patrick (1933) and referred by Drouet (1938) to *Oscillatoria princeps* Vauch., differs in having thin, smooth sheaths characteristic of the hormogonial phase of the latter species. Unlike *Oscillatoria princeps,* our plants are not at all tapering at the apices and the contents of the cell are not coarsely granular.

L. latissima should be compared with *L. Hummelii* Borge, a large species which is, however, smaller than the former, and one which has longer cells. Also the sheath in Borge's species is thinner and apparently not lamellate as in the Wisconsin plants.

NOSTOCACEAE

Anabaena wisconsinensis sp. nov.

PL. 2, FIG. 9–10.

Trichomata planctonica, recta aut subflexuosa, solitaria aut (saepius) ad fasciculos lamelliformes parvos laxosque efficiendos parallele aggregata, sine vagina, ad apices non attenuata; cellulis quadratis vel cylindratis, ad dissaepimenta constrictis, 3.6–4 μ diam., 3.6–10.8 μ long., intus pseudovacuolas magnas praedentibus; heterocystibus sphaericis aut compresso-globosis, 3.6–4.2 μ diam., una sola singulo in trichomate partem mediam occupante; gonidiis elliptico-ovatis ad late ovatis, ab heterocystibus remotis, primum constantibus ex 3 cellulis vegetativis dilatatis seriatim dispositis, quarum una sola plerumque maturescit ut omnia trichomata unicum gonidium habeant, si plura autem, gonidia, bina sunt, 7.2–8 μ diam., 10–13 μ long.

Trichomes planktonic, straight or slightly flexuous, solitary or (more often) aggregated in parallel fashion to form small, loose, flake-like bundles, without a sheath, not tapering at the apices; cells quadrate to cylindrical, constricted at the cross walls, 3.6–4 μ in diameter, 3.6–10.8 μ long; cell contents with large pseudovacuoles; heterocysts spherical or compressed-globose, 3.6–4.2 μ in diameter, only one in each trichome, centrally located; gonidia elliptic-ovoid to broadly ovoid, remote from the heterocysts, beginning their development as a series of three enlarged vegetative cells, usually only one of which matures so that each trichome has but a single gonidium, when more than one, occurring in pairs, 7.2–8 μ in diameter, 10–13 μ long.

Plankton in Post Lake, Langlade County.

This plant is remindful of *Aphanizomenon flos-aquae* (L.) Ralfs. It should be compared with *Anabaena aphanizomenoides* Forti from which it differs in the smaller size throughout, the ovoid shape of the gonidia and their location remote from the heterocysts rather than adjacent to them as in that species.

ALBION COLLEGE
ALBION, MICH.

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EXPLANATION OF PLATE 1

Fig. 1–2. *Chlamydomonas polypyrenoideum* sp. nov. × 650.
3. *Tetraspora lamellosa* sp. nov. × 500.
4–6. *Schizochlamys compacta* sp. nov. × 600.
7. *Ulothrix cylindricum* sp. nov. × 500.
8. *Geminella crenulatocollis* sp. nov. × 650.
9–10. *Hormidiopsis ellipsoideum* sp. nov. × 650.
11. *Pediastrum quadricornutum* sp. nov. × 650.
12–13. *Oocystis pyriformis* sp. nov. × 500.
14. *Tetraëdron asymmetricum* sp. nov. × 1500.
15. *Tetraëdron bifurcatum* var. *minor* var. nov. × 650.
16. *Tetraëdron cruciatum* var. *reductum* var. nov. × 650.
17. *Tetraëdron enorme* var. *pentaëdricum* var. nov. × 650.
18. *Tetraëdron limneticum* var. *gracile* var. nov. × 650.

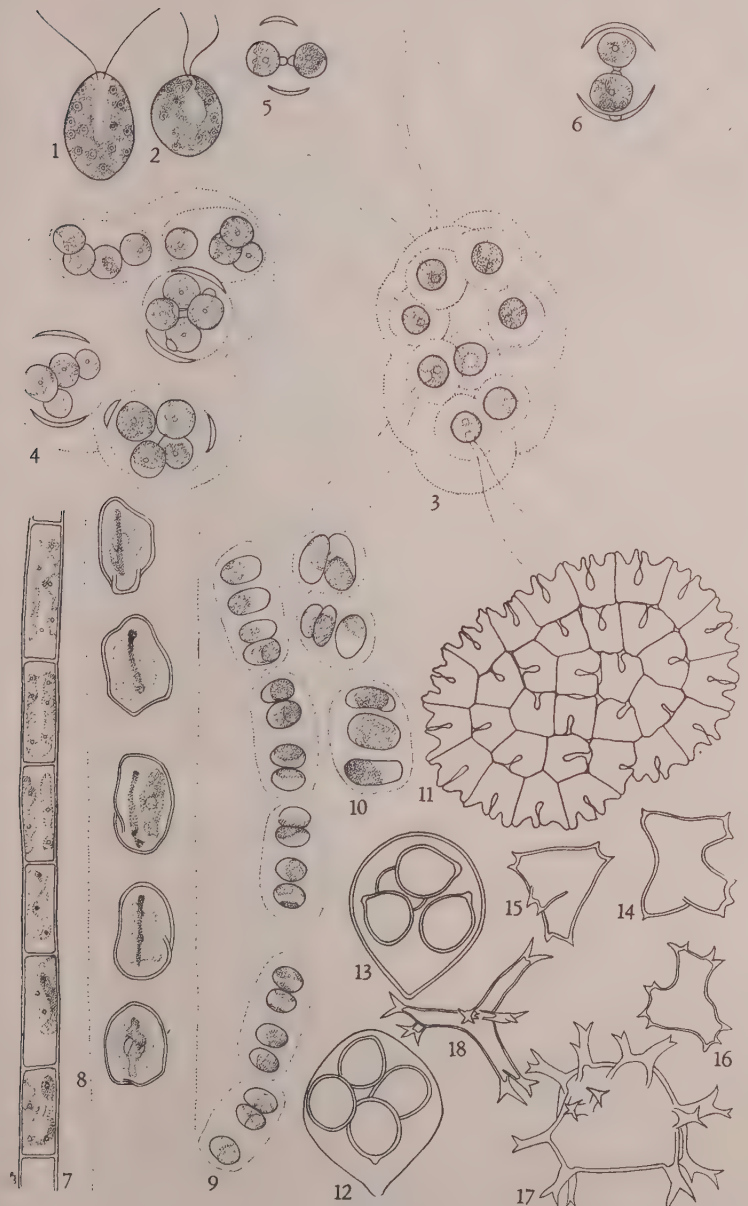

PLATE 1

EXPLANATION OF PLATE 2

Fig. 1–3. *Stigeoclonium pachydermum* sp. nov.; 1, × 250; 2, × 500; 3, × 1000.
4–5. *Draparnaldia Judayi* sp. nov. × 600.
6. *Pediastrum biradiatum* var. *emarginatum* fa. *convexum* fa. nov. × 600.
7. *Pediastrum muticum* var. *crenulatum* var. nov. × 700.
8. *Tetraëdron lobulatum* var. *crassum* var. nov. × 1000.
9–10. *Anabaena wisconsinensis* sp. nov. × 500.

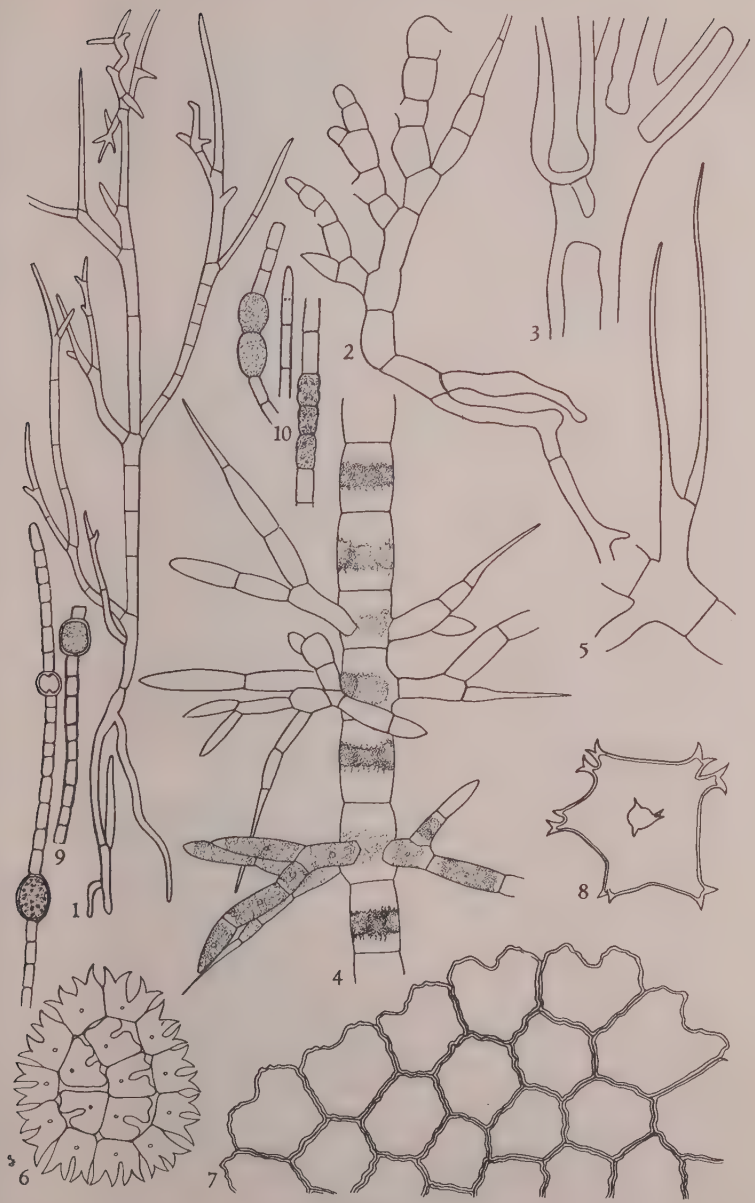

PLATE 2

EXPLANATION OF PLATE 3

Fig. 1. *Tetraëdron regulare* var. *granulata* var. nov. × 500.
2. *Tetraëdron regulare* var. *incus* fa. *major* fa. nov. × 500.
3. *Scenedesmus opoliensis* var. *contacta* var. nov. × 850.
4–5. *Tetradesmus Smithii* sp. nov.; 4, × 400; 5, × 1000.
6–10. *Stipitococcus apiculatus* sp. nov.; 6, × 700; 7–10, × 2000.
11–14. *Stipitococcus crassistipatus* sp. nov. × 1000.
15–16. *Ophiocytium desertum* var. *minor* var. nov. × 500.
17. *Ophiocytium elongatum* var. *major* var. nov. × 500.
18. *Mallomonas pseudocoronata* sp. nov. × 500.
19. *Mallomonas urnaformis* sp. nov. × 1000.
20–21. *Lagynion reductum* sp. nov. × 500.
22. *Lagynion triangularis* var. *pyramidatum* var. nov. × 650.
23–24. *Euglena breviflagellum* Prescott and Gojdics, sp. nov. × 650.
25–27. *Euglena elastica* sp. nov. × 500.
28–30. *Euglena minuta* sp. nov. × 500.
31. *Euglena oxyuris* var. *minor* var. nov. × 500.
32. *Phacus asymmetrica* sp. nov. × 600.
33. *Phacus Birgei* sp. nov. × 500.
34. *Phacus chloroplastes.* × 600.

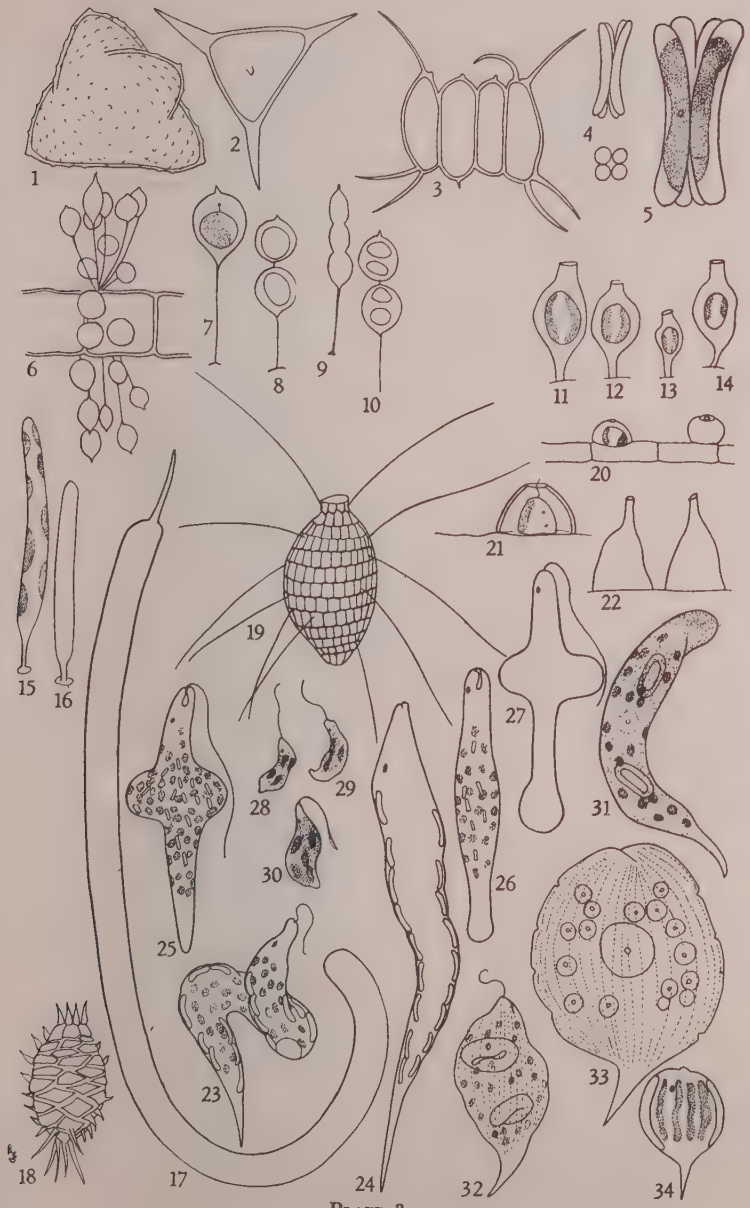
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PLATE 3

EXPLANATION OF PLATE 4

Fig. 1. *Phacus anacoelus* var. *undulata* fa. *major* fa. nov. × 600.
2–4. *P. chloroplastes* fa. *incisa* fa. nov. × 600.
5. *Phacus crenulata* sp. nov. × 600.
6–7. *Phacus spirogyra* var. *maxima* var. nov. × 500.
8. *Phacus pseudoswirenko* sp. nov. × 600.
9. *Phacus Segreti* var. *ovum* var. nov. × 600.
10. *Lepocinclis glabra* fa. *minor* fa. nov. × 550.
11. *Trachelomonas hexangulata* var. *repanda* var. nov. × 550.
12. *Trachelomonas mammillosa* sp. nov. × 550.
13. *Trachelomonas superba* var. *spinosa* var. nov. × 750.
14–16. *Gymnodinium caudatum* sp. nov. × 550.
17 19. *Glaucocystis duplex* sp. nov.; 17, × 250; 18, 19, × 350.
20. *Glaucocystis oocystiforme* sp. nov. × 650.
21. *Lyngbya latissima* sp. nov. × 375.

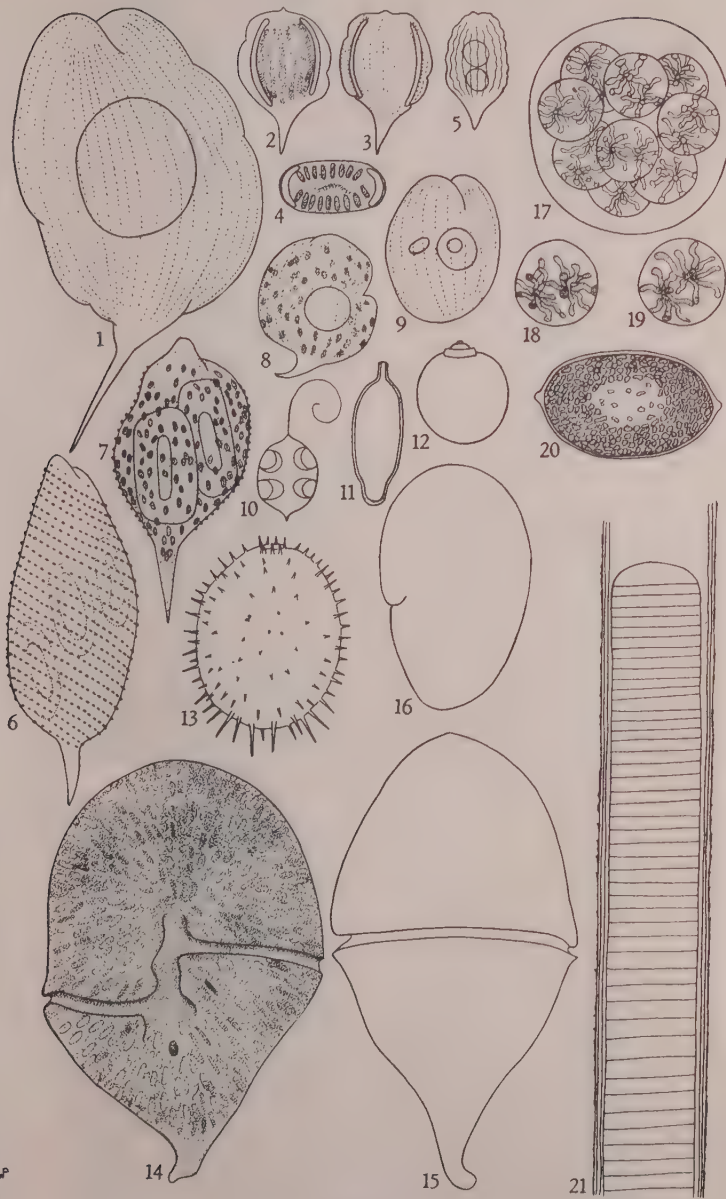

PLATE 4

EXPLANATION OF PLATE 5

Fig. 1–3. *Oedogonium Kjellmanii* var. *granulosa* var. nov.; 1, 2, × 275; 3, × 550.
4–5. *Oedogonium oviforme* fa. *gracile*. × 600.
6–7. *Oedogonium Smithii* sp. nov.; 6, × 500; 7, × 600.
8. *Oedogonium microgonium* sp. nov. × 600.
9. *Oedogonium spheroideum* sp. nov. × 300.
10. *Oedogonium Sawyeri* sp. nov. × 550.
11. *Oedogonium Kozminskii* sp. nov. × 360.
12. *Oedogonium polyandrium* sp. nov. × 550.
13–14. *Oedogonium oelandicum* var. *contortum* var. nov. × 600.

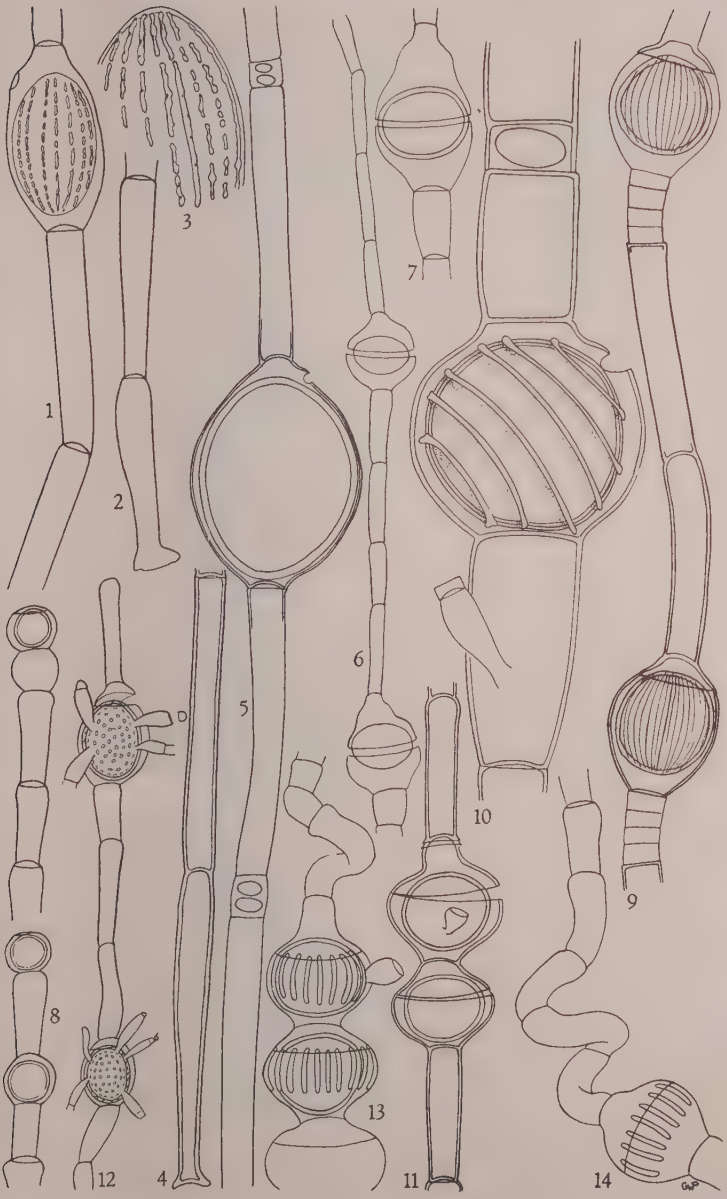

PLATE 5

1(3): 387–389 FARLOWIA January, 1944

MICROAPLANOSPORES OF VAUCHERIA

GILBERT M. SMITH

The asexual reproduction of *Vaucheria* by means of multiflagellate zoospores produced singly within sporangia is well known to all. So, also, is the production of an aplanospore instead of a zoospore within a sporangium. To judge from the literature, the transverse segmentation of the contents of a filament to form a uniseriate row of thick-walled aplanospores (hypnospores) is of relatively infrequent occurrence, and is found only in soil-inhabiting species of *Vaucheria*. Stahl (1879), the first to describe these hypnospores in detail, holds that their formation is induced by a drying out of the substratum. However, terrestrial species growing in the vicinity of Stanford University show that production of hypnospores is not always correlated with drying out of the soil. In central California the terrestrial species form hypnospores during the winter rainy season when the soil is saturated with water, but only when the minimal temperatures are near the freezing point. Dangeard (1940) has recently stated that the siphonaceous terrestrial algae producing hypnospores are not members of the genus *Vaucheria*. This conclusion is based upon his inability to obtain sex organs when the algae were grown in culture. Dangeard's studies raise the question as to whether or not spores may be formed in vegetative portions of filaments of *Vaucheria*.

Specimens of *Vaucheria Gardneri* Collins collected in a seepage pool from Lagunita, an artificial lake on the Stanford campus, show that spores may be formed in vegetative portions of a filament, and reveal a type of spore not previously described for the genus. These spores were present in many of the filaments collected on April 15, 1943. The station was revisited on April 18 to collect additional material, but in the meantime most of the algae had been killed by oil sprayed on the pool to kill mosquito larvae. Because of this it was impossible to obtain material showing the manner in which the spores are formed or their mode of germination after they are ripe.

Approximately 75% of the filaments in the collection bore sex organs, the remainder did not. Of the latter more than half of them contained small spores throughout their entire length. These filaments resemble fruiting specimens of *Phyllosiphon* and at first it was thought that they should be considered an aquatic species of that genus. Eventually the spores were also found in filaments with sex organs and thus definitely establishing that the vegetative filaments with spores were those of *V. Gardneri*.

The type of spore, previously unrecorded for *Vaucheria*, is an aplanospore and the term *microaplanospore* is proposed to distinguish it from the large aplanospore formed singly within a sporangium. Microaplanospores are formed throughout the length of a filament, not in sporangia

separated from the remainder of a filament by a transverse wall. All of the protoplasm of a filament divides to form microaplanospores and there are no remnants of cytoplasm between them. The distribution of the spores within a filament is uneven; they are densely packed in certain portions of a filament, in other portions they lie a short distance from one another (Fig. 1). This uneven distribution is thought to be an artifact caused by manipulation of the filaments in mounting them for examination under the microscope.

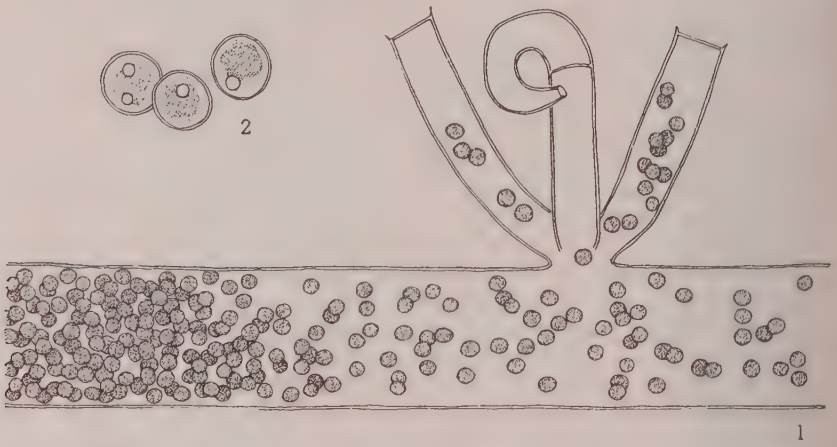

Fig. 1. Portion of a filament of *Vaucheria Gardneri* containing microaplanospores. × 325. **Fig. 2.** Microaplanospores. × 1300.

The microaplanospores are spherical, 5.5–6.5 μ in diameter, and have a wall somewhat thinner than the wall of the cell containing them. The protoplast contains a single irregularly lobed chloroplast and one or two droplets of oil adjacent to the chloroplast (Fig. 2). Nuclei were not observed, but the small size of the spores suggests that they are uninucleate. There are no pores or other openings in walls of filaments containing microaplanospores. Thus it is obvious that liberation of spores is by disintegration or decay of the parent cell wall. For reasons given above material was not available for study of germination of microaplanospores.

The Phyllosiphonaceae, a family universally recognized by phycologists, differ from all other families of the Siphonales in that they produce many small aplanospores within vegetative portions of filaments. The discovery of microaplanospores in *Vaucheria Gardneri* shows that production of many small aplanospores within vegetative portions of filaments is a feature common to Phyllosiphonaceae and to at least one member of the Vaucheriaceae. This might be taken as a justification for uniting the two families, but such a procedure seems unwarranted when

sexual reproduction is taken into consideration. All known members of the Vaucheriaceae regularly form antheridia and oögonia; whereas no antheridia, oögonia, or any other kind of sex organ has ever been observed in any of the *Phyllosiphonaceae*. Thus, pending discovery of sexual reproduction in *Phyllosiphon* and related genera, it is better to retain the family Phyllosiphonaceae.

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CALIFORNIA

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1(3): 391–393 FARLOWIA January, 1944

A NEGLECTED FIELD OF STUDY WITH THE DESCRIPTION OF A NEW LICHEN FROM CALIFORNIA

Albert W. C. T. Herre

I suggest that students of fresh water and aerial algae take up seriously the study of certain life forms that in this country have been greatly neglected. I refer to those algae found in lichens, whether they are one of the two essential lichen components or merely play a secondary part. Apparently no one in this country is working upon them with a view to finding out the changes they incur when enslaved by a fungus, as in ordinary lichens, or the way they are affected when more or less dominant as in the gelatinous lichens or other groups where the alga gives form and character.

European botanists long ago isolated the algae of some lichens and determined them with more or less exactitude. At various times pure cultures of different lichen algae and fungi have been made; sometimes these have later been synthesized and lichens grown until fruiting condition was reached. There is ample room for more such studies, but studies of a different character are likewise needed.

There are two other lines of research waiting for algologists to take up in connection with lichens. First, little or nothing has been done in this country upon the ecological and physiological changes or adaptations (and their resultant effect upon morphology) which an alga must sometimes undergo if it is to flourish or even survive as a prime factor in making what we call a lichen. That such changes do occur and are relatively common is well known to the few who have examined large numbers of lichens under the microscope. That they are quite unknown to the students of algae is not generally appreciated. For example, algologists are familiar with *Trentepohlia* and its orange red color, but they are not generally aware that in lichens containing this alga the orange red disappears and the alga is green. The student of lichens must therefore recognize the presence of *Trentepohlia* by other criteria than color. *Nostoc*, when growing in lichens, apparently never has heterocysts; in some lichens it forms characteristic chains, but in others it becomes compacted into masses very different from ordinary *Nostoc*, while in still others it breaks up into very small groups which can hardly be called chains. *Scytonéma*, too, breaks up into tiny groups or solitary cells, and does not at all resemble the pictures in the books. Thirty-six years ago my friend and teacher, Dr. Alexander Zahlbruckner, called my attention to the fact that Rivulariaceae (*Calothrix* and *Rivularia*) lost their basal heterocysts when growing in lichens, and were therefore hard to recognize.

Gloeocapsa is a common and well known free living alga, found in stagnant water and damp places. Algologists say the cells are always globose, more or less, and are never elongate or develop rhizoids. In

the new species of lichen described later, the alga is *Gloeocapsa,* section *Xanthocapsa.* In the interior of the lichen the algal cells are from 6 to 10 μ in diameter, arranged in groups 15 to 25 μ in diameter, surrounded by a thick gelatinous sheath. Near the under surface of the lichen the *Xanthocapsa* groups are much larger, and just within the surface some of the cells are seen to be somewhat elongate, instead of globose. From this stage they become two or three times as long as broad; a septum develops and the tip elongates still more until it projects beyond the lower margin of the lichen. This tip, which may or may not develop further septa, continues to lengthen until it becomes a very elongate, slender, and tubular rhizoid. The basal portion is the dark blue-green of the typical *Gloeocapsa* or *Xanthocapsa* color, with its characteristic gelatinous coat, but the burrowing tip soon becomes colorless in its outer part. The whole under surface of the lichen is covered with these rhizoids, which may be 5 mm. or more in length and form a dense mat that binds together the loose grains of the desert surface and holds the thallus firmly in position. In all other crustaceous lichens known to me the rhizoids are hyphal (fungal) threads only. I have no doubt that this is merely one instance of many that would give algologists new light upon the adaptions and physiology of algae.

Second, algologists should critically examine the algal constituents of various lichens and establish their correct identity. This is particularly needed in the case of those lichens containing blue-green algae. Many, if not most, of the published records have merely been copied from one author to another, without a thorough comparative examination of genera and authentic species, a practice of which I have myself been guilty.

Recent studies of large numbers of lichens sent from all over the United States, for identification, often reveal that lichens said to have *Nostoc* as their alga do not contain *Nostoc* at all. This is particularly true of members of the Pannariaceae, in which *Scytonema* or *Xanthocapsa* may be mistaken for *Nostoc.* For example, in *Pannaria lepidiota,* distributed by Cummings and Seymour as No. 122, Decades of North American Lichens, from Mt. Tamalpais, California, the alga is *Xanthocapsa,* not *Nostoc* as given in all published works.

In a number of lichens containing *Gloeocapsa* (*Xanthocapsa*) or *Scytonema,* I have also found *Aphanocapsa,* a blue-green alga not hitherto reported as occurring in any lichens. Whether it is an intrusive in the same way that *Nostoc* enters the hepatic *Anthoceros* and various foliose lichens, whether it is the sole algal component of a lichen, or whether it shares that onus with *Xanthocapsa* or *Scytonema,* is another problem for the algologist to solve. To conclude, our knowledge of the algal constituent of several families of lichens is but fragmentary, or even erroneous, and needs to be investigated by algologists who should settle their systematics and explore their hidden ecology.

All this is preliminary to the description of a new desert lichen from

California. Various workers, especially Dr. H. E. Hasse, have collected and studied the earth lichens of California deserts, and it was assumed that they were all known. The discovery of one belonging to a genus hitherto unknown in this country is therefore of some interest.

Anema Dodgei Herre sp. nov. (Pyrenopsidaceae)

Thallus monophyllus, squamulosus, pseudoparenchymaticus, crassus, salebrosus, inequalis, usque ad 5 mm. latitudine, substratum arcte obducens, late rhizino-affixus, niger, aut virescenti-niger vel opace olivaceo-umbrinus rigidus, cartilagineus, madefactus turgidus, subgelatinosus; gonidia *Xanthocapsa* sunt.

Apothecia parva vel mediocria, primum punctiformia, demum dilatata et urceolata demum lecanorina, margine thallino prominulo, usque ad 1.25 mm., lata rufa vel fusco-rufa; asci cylindrici; sporae octonae, monostichae, simplices, late ovoideae 10–22 μ longae, 5.5–11 μ crassae. Spermatia parva, bacilliformia aut subellipsoidea.

Ad terram desertorum, areas usque ad 8 cm. in diametro formans. Riverside and San Bernardino Counties, California.

Thallus monophyllous, thick, the squamules unequal in size, reaching a width of 5 mm. and forming a regular crust with rough irregular surface, pseudoparenchymatous within and closely adherent to the substratum by numerous rhizoids which reach a length of 5 mm. or more. Color, black or greenish black to dull olive brown; when dry the thallus is rigid and cartilaginous, becoming turgid and subgelatinous when wet. The alga is *Xanthocapsa*, with cells 6–10 μ in diameter, forming groups 15–25 μ in diameter, and surrounded by a thick gelatinous sheath.

The apothecia, reaching a width of 1.25 mm., are punctiform at first, becoming open and urceolate to lecanorine, with prominent thalline margin, the disk red to dark red; the epithecium is yellow, the thecium colorless, about 125 μ wide, the hypothecium gray or dusky gray, about 150 μ wide; the asci are cylindrical; the paraphyses jointed, coherent. Spores simple, colorless, 8, in a single row, broadly ovoid, 5.5–11 μ by 10–22 μ. Spermatia small, bacilliform or slightly ellipsoid.

Apparently an abundant earth lichen in the deserts of Riverside and San Bernardino Counties, California, forming crustose patches which may reach a width of 8 centimeters, more or less. Collected by Francis Drouet and J. Francis Macbride of the Field Museum, in 1941; No. 4621, type material, on barren soil a mile southwest of Essex, San Bernardino County, altitude about 1000 feet; Nos. 4624, 4626, and 4627, co-type material, on open places in the desert about 2 miles east of Danby, San Bernardino County; No. 4711, co-type material, on barren ground in open scrub forest just west of Desert Center, Riverside County; altitude about 900 feet.

Named for Dr. Carroll W. Dodge, of the Missouri Botanical Garden, in recognition of his contributions to the study of lichens.

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1(3): 395–467 FARLOWIA January, 1944

MARINE FUNGI: THEIR TAXONOMY AND BIOLOGY [1]

E. S. Barghoorn and D. H. Linder

INTRODUCTION

Although thousands of species of fungi are known from what may be considered terrestrial habitats, and a much lesser number from freshwater habitats, very few have been described from marine environments, although a number of the latter do exist. Cotton (1), in 1907, in summarizing the situation, noted that fifteen species had been described as marine forms, and to these he added a sixteenth. Of these species, six were members of the phycomycetous order Chytridiales and ten of the ascomycetous sub-class Pyrenomycetes. Since Cotton's paper, some of the species have been relegated to synonymy, but in 1915 Sutherland (14, 15, 16) described fourteen new species of Pyrenomycetes, two of which were the types of new genera. A year later, he (17) added a number of new species of Fungi Imperfecti. Petersen (6) made a study of the chytridiaceous forms parasitic on algae, and more recently Sparrow (11, 12, 13) has added to our knowledge of that group. The only marine fungi that have been published to date as occurring on plant remains, other than algae, are three species of *Ophiobolus* described by Ellis (2), Saccardo (10), and Mounce and Diehl (5). The last named authors described *Ophiobolus halimus* which apparently caused considerable damage to the eelgrass, *Zostera marina.* Subsequently Renn (7, 8, 9) demonstrated that a species of *Labyrinthula* (Myxomycete), later determined by Young (19) as *L. macrocystis* Cienk., actually was the agent that caused the destruction of eelgrass over a considerable geographic range. In view of these later findings, there arises the thought that *Ophiobolus halimus* may be a secondary parasite or indeed might even be saprophytic, thus placing the species in the same category as those which are to be considered in the present paper.

With the exception of the papers of Saccardo, Ellis, and Mounce and Diehl, there is, as far as the authors are aware, only one published reference to the occurrence of marine fungi on phanerogamic plant remains. This is a brief note by Johnson and McNeil (4) indicating the presence

[1] This study is a joint endeavor arising from a project undertaken by E. S. Barghoorn on the microbiological factors responsible for the decomposition of submerged plant remains in the sea. D. H. Linder has made all contributions to the taxonomy and relationships of the fungi described. Problems encountered in the isolation and culturing of the various species have been worked out together. E. S. Barghoorn has undertaken the field work, has gathered together most of the specimens and pertinent collection data, has made the isolations of pure cultures and has carried out the experimental studies.

The present paper is one of a contemplated series of investigations on the various microbiological, chemical and physical factors involved in the decomposition or preservation of submerged plant materials.

of a seawater fungus in the decomposition of hardwood timbers in the port of Sydney, Australia. No description of the fungus is made beyond mention of the fact that it was referred to the class Ascomycetes and that "some timbers are weakened by a softening of the surface fibres to a depth of one-quarter of an inch of truewood in a period of seven years immersion."

The fact that a score or more of species have been described as occurring in the sea is of importance since it shows that fungi not only tolerate salt water, but indeed that marine conditions furnish a normal habitat for the relatively small number of fungi that have become adapted to it.

The fungi considered in this study differ from the majority of those already mentioned in that they do not occur on algae, but on wood and plant remains in the sea. All of the species were obtained from specimens of wood that had been either submerged continually from five months to one year and were below low tide level for the entire period, or were exposed in the inter-tidal zone where they were subjected twice a day to immersion in seawater. Under these conditions, it is highly improbable that the fungi are terrestrial forms which penetrated the wood after it had been removed from the sea, or before it had been immersed. This fact becomes evident when it is realized that the majority of the samples were examined within one to three days of their removal from the marine location, a time much too short to permit the formation and fruiting of the ascigerous stage, and even too brief a time for the establishment of any extensive colonies of the conidial phases. Another convincing line of evidence that these fungi are normally marine in their occurrence is the fact that the majority of them are very tolerant of sea water, even to the extent of growing on artificial media made with sea water of three times the normal saline concentration, as will be shown later in this study. For the present, the collection data given below may serve to give some insight into the conditions under which the various samples of wood and cordage have become inoculated by the fungi.

SPECIMEN COLLECTION DATA

Specimen	*Location*	*Submerged*	*Removed*	*Conditions*	*Type of Specimen*
1	Old Concord Wharf, Portsmouth, New Hampshire.	Sept. 23/41	May 19/42	4 ft. below low water.	Test block.
2	Searsport, Maine.	Sept. 30/41	May 26/42	5 ft. below low water.	Test block.
3	Woods Hole, Mass.	Oct. 13/41	June 13/42	7–8 ft. below low water. 5 ft. above mud.	Test block.
4	Baylies Wharf, Fall River, Mass.	Feb. 1942	July 18/42	8 ft. below low water.	Test board.
5	Tide flats, No. Truro. 200 ft. from shore at low tide.	?	June, 1942	Covered by 8 ft. of water at high tide.	Driftwood embedded in sand.
6	Chelsea, Mass.	1918	May, 1942	Near high tide line.	Pile chip.

SPECIMEN COLLECTION DATA—*Continued*

Specimen	*Location*	*Submerged*	*Removed*	*Conditions*	*Type of Specimen*
7	Same as 5.	?	June, 1942	Same as 5.	Driftwood.
8	Same as 5.	?	June, 1942	Same as 5.	Driftwood.
9	Same as 5.	?	June, 1942	Same as 5.	Driftwood.
10	Woods Hole, Mass.	March 6/42	Aug. 5/42	Below low water at all times.	Test board.
11	B. & M. Bridge, Portsmouth, N. H.	Dec. 29/41	Aug. 25/42	Below low water at all times.	Test block.
13	Bucksport, Maine.	Dec. 19/41	Aug. 25/42	Below low water at all times.	Test block.
14	Provincetown, Mass.	1933?	July 24/42	2 ft. above low water.	Pile chip. Cold Storage Wharf.
15	Woods Hole, Mass.	April 6/42	Sept. 5/42	Below low water at all times.	Test board.
16	Salem, Mass.	May, 1942	Sept. 18/42	Below low water at all times.	Test board.
17	Saybrook, Conn.	May 1/42	Oct. 1/42	Below low water at all times.	Test board.
18	Provincetown, Mass	?	July 24/42	Tide flats. Covered 8 ft. at high water.	Timber embedded in sand
19	Newburyport, Mass.	May 25/42	Oct. 16/42	Below low water at all times. Salinity low.	Test board.
20	Woods Hole, Mass.	?	Aug. 24/42	Intertidal zone.	Manila rope.
21	Rockland, Maine.	March 10/42	Nov. 18/42	Below low water at all times.	Test block.
22	Thomaston, Maine.	Sept., 1938	Nov. 27/42	Below low water at all times.	Back board for test blocks.
23	Provincetown, Mass.	?	Sept. 24/42	3 ft. above low water.	Submerged stump.
24	Provincetown, Mass.	?	Sept. 24/42	3 ft. above low water.	Submerged stump (bark).
25	Provincetown, Mass.	?	Sept. 24/42	3 ft. above low water.	Submerged stump.
26	Provincetown, Mass.	?	Sept. 24/42	3 ft. above low water.	Submerged stump.
27	Provincetown, Mass.	1900 or 1901	Sept. 24/42	4–5 ft. above low water.	Jetty bulkhead E. Breakwall, Provincetown.
28	Provincetown, Mass.	?	Sept. 24/42	2 ft. above low water.	Driftwood.
29	Provincetown, Mass.	?	Sept. 24/42	2 ft. above low water.	Driftwood.
30	Bridgeport, Conn	Dec. 8/41	Dec. 21/42	Below low water.	Test board.

Since these fungi appear to be terrestrial forms that have become adapted to marine conditions, it may not be amiss at this time to point out briefly some of the modifications that have occurred which appear to make these forms better adjusted to their present environment. One of these changes which, with few exceptions, appears to hold for all species belonging in the Pyrenomycetes, is that the ascus wall breaks down at an early stage, very shortly after the ascospores have been delimited. In

some cases, the ascus wall can be observed to be deeply eroded by the time that the spores have been delimited. Exactly why dissolution of the ascus wall is so common is difficult to conjecture, although it may be presumed that with the breakdown of the wall, there is an increase in the amount of hygroscopic material which, in addition to that already formed within the ascus, aids in discharging the spores into the aquatic environment. When it is realized that the greater number of terrestrial species are dependent for dispersal upon the forceful discharge of the spores into the air where they are carried by air currents, it is apparent that a substitute method would be more effective for the dispersal of spores of the marine species. The deliquescence of the ascus wall, then, would seem to answer this need. In addition to this almost general characteristic, there is another that immediately draws attention, viz., the presence of processes on the spores that serve to keep the spores suspended for a greater length of time in the water. Thus, *Peritrichospora*, which appears to be closely allied to the terrestrial genus *Ceriospora*, is characterized by numerous cilium-like processes that are produced around the middle septa of the spores (Pl. V) and formed after the spores have been freed from the ascus. In addition to the cilium-like processes, the spores have an appendage at either end which soon becomes modified and eventually deliquesces. These appendages appear to serve for the attachment of the spores to the new substratum since when the spores are mounted in water, the softened ends often cling to the cover glass or slide and can be removed from their point of attachment only after considerable agitation of the mount. Similarly, the spores of *Remispora*, while not having the cilium-like processes, are equipped at each end with a pair of appendages which appear to serve both for the attachment of the spores to the substratum, as well as to assist in suspending the spores in water and facilitating their dispersal. Unlike the appendages of the spores of *Peritrichospora*, those of *Remispora* appear to be in some way connected with the astral rays of the nucleus since they are already formed within the ascus, and, while the ascospores are immature, nearly surround them (Pl. III, figs. 7–10). As another example of adaptation in the pyrenomycetous genera, the species of *Halophiobolus* furnish excellent illustration of their suitability for aquatic dissemination. In these species, the spores (Pl. VI) are filamentous and slender and sink less readily than would the rounded or ellipsoid spores. While such filamentous spores are found in the discomycetous genus *Vibrissea* which grows on decaying wood or leaves in freshwater habitats, and are very common in the hypocreaceous genus *Cordyceps* which, with few exceptions, parasitizes insects and is thus terrestrial, the two ends of the spores of the species of *Halophiobolus* are equipped with modified tips which are somewhat gelatinous and thus are capable of attaching the spores to any substratum with which they come in contact. Indeed, it is very difficult because of the adhesiveness of the tips, to discharge the spores from a glass pipette.

A similar difficulty is encountered in handling the spores of several other species for the following reason. Surrounding the spore there is a jelly-like sheath or wing-like structure (Pl. III, fig. 1–4) which becomes more and more diffluent upon the release of the spores into water. Owing to the tenacity of the jelly, the spores tend to cling to any object with which they come in contact, even to such smooth surfaces as glass. A spore modification closely resembling this is reported in the case of an aquatic (freshwater) Ascomycete described by Weston (18) in which he showed that the jelly firmly attaches the spore to the substratum or to any surface upon which it settled. Thus it can be seen that there are special modifications of the ascospores which not only aid in keeping the spores suspended in water, but which also assist in holding them in contact with any solid substratum which they encounter in the water. Among the conidial forms, perhaps the most outstanding is *Orbimyces* (Pl. I, fig. 5–6), the conidia of which are dark and spherical or subspherical, and equipped with finger-like processes which serve as a sort of parachute to keep the conidia from sinking too rapidly. This modification of the conidium parallels that recently described by Ingold (3) for a number of freshwater Fungi Imperfecti which also are characterized by their form and the number of appendages they bear. The morphological response of *Orbimyces* to its aquaeous habitat is so similar to that of the several species described and delineated by Ingold that there seems no reason to deny that *Orbimyces* is a form morphologically adapted to marine conditions, just as are the other species to their freshwater habitat.

The morphological modifications of the ascospores and conidia lead one to speculate as to the ancestry of these forms and the rôle that they play in the scheme of things. Of the former, there is so little evidence on which to base theories that it does not seem worth while entering into a discussion. The most that can be said is that these forms belong in the same genera or in genera closely related to those that occur in terrestrial habitats. As regards the place that these forms take in the natural cycle of events, it would seem that they act more or less in the same capacity as wood-rotting fungi in forests. The action on plant remains does not appear to be as rapid as that brought about on land, but unquestionably they play an important rôle since many of the forms are strong destroyers of cellulose, pectic substances, and other carbohydrates, and to a lesser extent of lignin. Their economic significance to man is at present being further studied, but from the evidence now available there is not the least doubt that these forms are instrumental in speeding the rate of decay of wooden piling and particularly of cordage by the successive and continuous decaying of the outer parts that are submerged intermittently or all the time in salt or brackish water. Since rope is essentially cellulose, certain of these fungi play a very important part in its deterioration. One of our collections, already listed, demonstrates this fact most clearly for the samples of rope not only were penetrated

in all directions by fungous hyphae, but the fungi were producing large numbers of fruiting bodies all over the surface of the substratum and producing spores in great numbers, as evidenced by the number of mature asci still present in a goodly proportion of the fruiting bodies. But sufficient has been written at this stage to indicate the potential importance of at least a fair proportion of these fungi. More extensive studies on their physiology are being made, the results of which will appear later in this and in subsequent papers.

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I. CLASSIFICATION OF THE MARINE FUNGI

DAVID H. LINDER

In undertaking the classification of the marine fungi that occur on plant remains, the writer had little idea of the number of species that would be encountered in so short a time, nor did he realize how great would be the diversity of forms that would be discovered. The adaptation of the species in some cases has been rather striking, as has already been pointed out in the introductory pages, and it is this very factor that makes difficult the task of relating the genera and species to those already described from the terrestrial habitat. These points have impressed on the writer the need for careful study of the species, and yet despite the best of intentions, it has been necessary to describe numerous new species or even genera, since, with but few exceptions, it has been impossible to place the organisms in genera or species that have been described to date. It is recognized, however, that with additional collections and a greater assemblage of facts with which to work, forms will be found that will throw considerably more light on the relationship between these species that are about to be described and those that have already been described from a terrestrial habitat. Such information, while highly desirable, is not at this stage a prerequisite and for this reason the present efforts should be considered merely as providing the names for those organisms with which the student of the biology, physiology, and economic importance of these fungi has to deal.

There have been difficulties in connection with the study of these marine fungi, not the least of which has been the paucity of material for examination. Occasionally also, a colony that appeared on gross examination to consist of one species, proved on sampling to be a mixture. Thus it early became evident that in order to study these forms and to make a careful record of their characters, it was first necessary to dissect out the pycnidia

or perithecia and make temporary microscopical preparation from which the structures could be studied and measured, and drawings made under the low power of the microscope and with the aid of the camera lucida. Once this preliminary work had been accomplished, the specimen, mounted in acid-fuchsin-lactophenol, was gently crushed while being observed under the low power of the microscope, after which further observations were made of the more detailed structures. When these studies were completed, the specimens were remounted in glycerine-phloxine by the Diehl[1] double cover glass method, and these slides, it is hoped, will serve as a permanent reference for future investigators.

As a matter of convenience, the fungi are arranged in this paper more or less in accord with Saccardo's system:

Fungi Imperfecti

Sphaeropsidales
Moniliales

Pyrenomycetes

Amerosporae: 1-celled spores
Didymosporae: 2-celled spores
Phragmosporae: 3- or more celled spores
Scolecosporae: filamentous, septate or non-septate spores.

It is obvious that this arrangement has very little if any phylogenetic significance. The most that can be said in its favor is that it allows for the more ready location of a desired species, a point of more importance to the practical worker than to the taxonomic mycologist who is, or should be, interested in the natural relationship of the different organisms. Because the writer feels that these marine fungi are of considerable economic importance, convenience has governed the order of presentation of the species.

FUNGI IMPERFECTI

SPHAEROPSIDALES

Phialophorophoma Linder, gen. nov.[2]

Pycnidiis atris, subcarbonaceis, subglobosis vel ellipsoideis, ostiolatis, immersis; conidiophoris hyalinis, simplicibus vel infra ramosis; conidiis endogenis, hyalinis, ellipsoideis, simplicibus.

Pycnidia black, subcarbonaceous, subglobose or ellipsoidal, ostiolate and immersed in the substratum. Conidiophores hyaline, simple or branched below, lining the cavity of the pycnidium. Conidia endogenous, hyaline, ellipsoidal, 1-celled.

The genus receives its name from the fact that the conidiophores, like those of *Phialophora*, produce the conidia endogenously and thus immediately distinguish this sphaeropsidaceous fungus.

[1] Diehl, W. W. Science, N. S. **69**: 276. 1929.

[2] The writer wishes to acknowledge his thanks to Dr. Rolf Singer for his considerable assistance in preparing the Latin descriptions.

Phialophorophoma litoralis Linder, sp. nov.

Plate I, figs. 7–9.

Pycnidiis in maculis atratis, immersis, atris et subcarbonaceis (vel atro-fuscis sub microscopio) late-ovoideis vel ellipsoideis, 175 μ longitudine, 118 μ crassitudine, 116 μ altitudine, ostiolo excluso; ostiolis late-conicis vel papilliformibus, leniter exsertis. Conidiophoris (phialidiis) hyalinis, 7–10.5 x (2.5)–3–3.5 μ, sursum attenuatis et ad apicem torque cupuliformi terminatis; conidiis hyalinis, ellipsoideis, piriformibus, vel crepiduliformibus, plerumque biguttulatis, 2.5–3.5 x 1.5 μ, endogenis.

Pycnidia formed in the blackened area of the woody substratum, immersed, broadly ovoid or ellipsoid, black, subcarbonaceous (deep fuscous under the microscope) 175 μ long, 118 μ wide, 116 μ high excluding the eccentric, broadly conoid or papilliform ostiole. **Conidiophores** (phialides) hyaline, 7–10.5 x (2.5)–3–3.5 μ, tapering upward to a short cylindrical neck that is surmounted by a flaring cup-shaped collar. **Conidia** hyaline, ellipsoid to slipper- or pear-shaped, mostly biguttulate, 2.5–3.5 x 1.5 μ, produced endogenously.

Specimens examined: Massachusetts, Provincetown, on oak bark about two feet above the low tide level, Sept. 24, 1942, *E. S. Barghoorn, 24;* Charleston, pilings (oak?) in Boston Harbor, May, 1942, comm. *Ruth Lindquist.* **Type.**

This species and genus is characterized by the endogenous production of the conidia. Judging by the fact that in other groups the endogenous phialospores represent spermatia, it is not unlikely that this species represents the haploid phase of some Pyrenomycete.

Diplodia orae-maris Linder, sp. nov.

Plate I, figs. 1–3.

Pycnidiis pro parte immersis, ellipsoideis, membranaceis vel vetustis subcarbonaceis, supra atris vel atro-fuscis, infra, in parte immersa leniter coloratis, 270 μ longitudine, 160 μ altitudine, 150 μ crassitudine; conidiophoris hyalinis 1-cellulatis, 6.5–8.5 x 2.5–3.5 μ, cellulis hyalinis, bullatis, singillatim oriundis; conidiis ovoideis vel ellipsoideis, brunneis, uniseptatis, 7.5–8.25 x 3.5–4 μ.

Pycnidia partially immersed, ellipsoid, membranous or with age be coming subcarbonaceous, black or deep fuscous above, lighter colored in the lower submerged portions, 270 μ long, 160 μ high, 150 μ wide, the ostiole broadly papillate. **Conidiophores** hyaline, 1-celled, 6.5–8.5 x 2.5–3.5 μ, arising singly from the hyaline, bullate cells that line the greater part of the pycnidial cavity. **Conidia** ovoid to ellipsoid, brownish, 2-celled, 7.5–8.25 x 3.5–4 μ.

Specimen examined: **California,** Long Beach, on driftwood, Feb., 1943, *V. G. Dethier* (c). **Type.**

MONILIALES

Botryophialophora Linder, gen. nov.

Mycelio aerio albo, bombycino; conidiophoris (phialidiis) plerumque tribus vel compluribus ex cellula amplificata, globosa oriundis sive conidiophoris singulariter oriundis, ergo cellula globosa frequenter destitutis; conidiis hyalinis conglobatis.

Sterile mycelium white or light colored, cottony (in culture). Conidiophores (phialides) usually three or more from an enlarged globose or subglobose basal cell which is produced pleurogenously on the main hyphae or their branches; occasionally the conidiophores are produced singly when they may be either pleurogenous or else acrogenous at the ends of short side branches. Spores hyaline or light colored and tending to aggregate in globose clusters.

Botryophialophora marina Linder, sp. nov.

Plate I, fig. 4.

Mycelio aerio albo vel vetusto dilute fusco, bombycino, ramoso, distanter septato, 5–10 μ diametro; conidiophoris (phialidiis) hyalinis, plerumque 3–20 e cellula amplificata, globosa vel subglobosa pleurogena oriundis, primum simplicibus deinde infra ramosis, vasiformibus, 3.5–8.5 x 1.5–2.5 μ; conidiis hyalinis, globosis, 2–3 μ diametro, vacuolatis, frequenter in capitulis globosis albidisque aggregatis.

Aerial mycelium white or becoming dilute fuscous with age, cottony and tending to become repent, loosely branched, distantly septate, 5–10 μ in diameter. **Conidiophores** (phialides) hyaline, rarely 1–2 borne pleurogenously or acrogenously on the ends of short branches, usually from 3–20 or more arising from a globose or subglobose enlarged cell which arises pleurogenously on the main hyphae, at first simple becoming branched below, flask- or vase-shaped, 3.5–8.5 x 1.5–2.5 μ. **Conidia** globose or subglobose, hyaline, 2–3 μ in diameter, usually with a large central vacuole, tending to aggregate in white spherical heads.

Specimens examined: **Massachusetts,** North Truro, on driftwood covered by eight feet of water at high tide, *E. S. Barghoorn, 8.* **Type.**

The above description was drawn from the fungus as it appeared in culture. It seems quite likely that the species on its natural substratum and especially in its native environment would be so inconspicuous as to be overlooked. Furthermore, the fungus, as is evidenced by the fact that the spores are small and are produced in phialides, may in the future prove to be the conidial or spermatial stage of some ascomycetous species.

Orbimyces Linder, gen. nov.

Mycelio aerio fusco, atro-olivaceo vel subnigro, distanter septato; conidiis pleurogenis in dentibus sporogenis brevibus, globosis, nitide-nigris coronam ex 3–4 appendiculis digitatis, fuscis, septatis consistentem et circum basem turgidam appendiculae unicae erectae dispositis.

Aerial mycelium light fuscous to dark olivaceous or nearly black, distantly septate. Conidia pleurogenous on short sporogenous teeth, globose shining black and bearing a crown of three to four fuscous, finger-like appendages that are arranged radiately around the somewhat swollen base of a single central appendage which, like the radiate appendages, is fuscous and septate.

Orbimyces spectabilis Linder, sp. nov.

Plate I, figs. 5–6.

Coloniae fuscae vel atro-olivaceae, nonnihil jubatae; mycelio bombycino laxo undulatoque, sparse ramoso et interdum anastomosante, distanter septato, 1.5–3.5 μ

diametro; conidiis pleurogenis in dentibus sporogenis, subglobosis, 24–33 x 23–29 μ, nitide-nigris et coronam e 3–4 appendicularum digitiformium, fuscarum, septatarum, consistentem et circum basem turgidam appendiculae unicae erectae dispositis.

Colonies fuscous to dark olivaceous, somewhat tufted. **Mycelium** cottony loose and undulate, sparsely branched and occasionally anastomosing, distantly septate, 1.5–3.5 μ in diameter. **Conidia** borne pleurogenously on the lower parts of the hyphae on short inconspicuous hyaline sporogenous teeth, readily deciduous, subglobose, 24–33 x 23–29 μ, shining black and bearing at the distal end a crown consisting of 3–4 fuscous, septate, finger-like appendages that are arranged around the somewhat swollen base of the central erect appendage that is of similar length, color, and septation as the radiate members.

Specimen examined: **Massachusetts,** Charleston, on piling (oak?) in Boston Harbor, May, 1942, communicated by *Ruth Lindquist.* **Type.**

This genus and species receives its name from the fancied resemblance of the conidia to the orb which is a part of English royal regalia.

Alternaria maritima Sutherland, New Phytol. **15**: 46–47. *figs.* 5–7. 1916.

Plate II, fig. 1.

"Mycelium diffused; conidiophores erect, simple, rarely slightly branched, brown; conidia in simple or branched chains, pyriform with neck-like apex, dark brown, verrucose, 30–50 μ x 12–18 μ."

Specimen examined: **Massachusetts:** Woods Hole, isolated from test block submerged seven to eight feet below low tide level on Oct. 13, 1941, and removed June 13, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 3a.*

The present specimen seems to agree closely enough with that described by Sutherland, whose description is quoted above, to consider the two as belonging to the same species. The spores of the specimen communicated by Barghoorn, however, are smooth to slightly roughened and measure (16.5)–21.5–38–(60, including the neck-like appendage) x (8.25)–10–11.5–(13.5) μ. Since species of *Alternaria* and *Macrosporium* show such extreme variation in culture, with age, and in different environmental conditions, the slight variation just mentioned does not seem to warrant the erection of a new species in an already large genus.

Sutherland reports that in England this species is a saprophyte on *Laminaria* fronds, and this would indicate that the species could grow on wood where it might readily attack pectin and cellulose, among other carbohydrates.

Helicoma maritimum Linder, sp. nov.

Plate II, figs. 2–6.

Mycelio sterili in substrato plerumque immerso, ramoso, dilute vel atre fusco; conidiophoris magnitudine mutabilibus, usque ad 100 μ longitudine, 3–5 μ diametro, vulgo ramulis rectis vel curvulis mycelio sterili oriundis, distanter septatis; conidiis fuscis vel atro-fuscis, plerumque adumbratione aliquantulum quadrata gaudentibus

4- to 10-septatis, septis atro-fuscis, filis in spiras 1¾ vel bis convolutis, 8.5–10 μ diametro, spiris 23–26.5 μ diametro.

Sterile mycelium mostly in the substratum or spreading over its surface, branching, dilute to deep fuscous. **Conidiophores** variable in size, up to 100 μ long, 3–5 μ in diameter, usually appearing as hyaline or dilute fuscous, erect or irregularly bent branches from the sterile mycelium, distantly septate. **Conidia** deep fuscous or almost black, often with a squarish outline, 4- to 10-septate, the septa deep fuscous or black, the spore filament 8.5–10 μ in diameter, 1¾–2 times coiled, the coil 23–26.5 μ in diameter.

Specimens examined: **Maine,** Searsport, on test block immersed five feet below low tide level on Sept. 30, 1941, and removed May 26, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 2;* **Massachusetts,** Woods Hole, on test block immersed seven to eight feet below low tide level on Oct. 13, 1941, and removed June 13, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 3a;* Woods Hole, on test board submerged below low tide level Mar. 6, 1942, and removed Aug. 5, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 10b.*

Although the majority of the Helicosporeae are terrestrial, there is little doubt of this species belonging in the marine habitat since in a freshly removed test board that had been immersed for eleven months, the spores of this fungus were discovered on the wood under and around incrusting algae, sponge spicules and other debris.

Helicoma salinum Linder, sp. nov.

Plate II, figs. 8–11.

Coloniae effusae, sparsae; conidiophoris ramulis brevibus, dilute fuscis mycelio sterili oriundis, cellula terminali obscuriore atque atro-fusco, cellula extrema globoso-inflata est, atro-fusca; conidiis acrogenis, maturitate fuscis praeter cellulas duas basales dilutius coloratas, 11–26-septatis, ad septa leniter constrictis, filis in spiras 1¾–4½-convolutis, 5.5–8 μ diametro, ad basem attenuatam 3.5–4.5 μ diametro, spiris 28–39 μ diametro.

Colonies effuse, sparse. **Conidiophores** as rather short slender side branches from the repent mycelium, light fuscous except for the terminal cell which is darker or else when it is globose, inflated and deep fuscous. **Conidia** acrogenous, at first darkest near the apex but later, except for the one or two lighter colored basal cells, becoming uniformly fuscous, 11- to 26-septate, slightly constricted at the dark septa, 1¾ to 4½ times coiled, the filament 5.5–8 μ in diameter, gradually tapering to 3.5–4.5 μ in diameter near the base which is rounded-truncate; the coiled spore 28–39 μ in diameter.

Specimens examined: **Maine,** Bucksport, on test block below water at all times, submerged Dec. 19, 1941, removed Aug. 25, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 13;* **Massachusetts,** North Truro, on driftwood covered by eight feet of water at high tide, June, 1942, *E. S. Barghoorn, 5.* **Type; Connecticut,** Saybrook, on test board below low tide level at all times, immersed May 1, 1942, removed Oct. 1, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 17.*

This species in the younger stages resembles *H. maritimum*, but may in most cases be readily distinguished by the fact that the conidia tend to coil in three instead of two planes, and by the more numerous coils and septations of the spores.

Speira (Cattanea) **pelagica** Linder, sp. nov.

Plate II, fig. 7.

Mycelio sterili in substrato immerso, hyalino, ramoso; conidiophoris hyalinis, simplicibus vel rarissime septatis, 16–28 x 1.5–2 μ.; conidiis atro-brunneis, plerumque 24.5–30 x 16.5–24.5 μ., versiformibus, primum cellulis in ordinibus tribus, raro duobus vel quattuor, ex cellula unica basali oriundis deinde saepe irregulariter multiseriatis, septis atro-brunneis vel sub-atris, cellulae 5–6.5 x 5–5.75 μ metientibus.

Sterile mycelium mostly within the substratum, inconspicuous, hyaline or locally brownish and branched. **Conidiophores** hyaline, simple or very rarely septate, slender, mostly 16–28 x 1.5–2.5 μ. **Conidia** dark brown under the microscope or black under the hand lens, mostly 24.5–30 x16.5–24.5 μ, at first nearly flat with a single cell giving rise to three rows of 6 to 7 cells, rarely two or four rows, but later through division of the cells the spores tend to become terete, irregularly multiseriate and to assume very irregular shapes, occasionally branched and mitten-shaped, the septa dark brown to nearly black, the cells variable in size but mostly 5–6.5 x 5–5.75 μ.

Specimen examined: **Massachusetts,** on driftwood covered by eight feet of water at high tide, July 24, 1942, *E. S. Barghoorn, 18.* **Type.**

The conidia of this species in the early stages of formation are typical of the section Cattanea of **Speira** and the above description is based mainly on this phase. Occasionally spores are found in which there has been considerable proliferation of the cells and in such instances they are strongly reminiscent of *Sporodesmium cellulosum* Sacc.

PYRENOMYCETES

AMEROSPORAE

Samarosporella Linder, gen. nov.

Peritheciis nigris, carbonaceis, immersis, globosis, ostiolatis; ostiolis papilliformibus et paullulum exsertis; paraphysibus absentibus; ascis fusoideis, apicibus rotundatis instructis; ascosporis 4–8, hyalinis, elongato-ellipsoideis vel fusoideis, alatis; ascosporis abortivis non alatis et multum minoribus.

Perithecia imbedded, black and carbonaceous, globose and ostiolate. The ostiole papilliform and slightly exserted beyond the substratum. **Paraphyses** absent. **Asci** fusoid with rounded apices, deliquescing, 4–8-spored and usually with some of the spores aborted. **Ascospores** hyaline, elongate-ellipsoid or somewhat fusoid, with irregular hyaline wings; the aborted ascospores much smaller, ovoid or ellipsoid and devoid of hyaline wings or else with very rudimentary ones.

This genus, because of the winged spores, appears to be related to *Samarospora* of Rostrup (Bot. Centralbl. Beih. **3:** 3. 1893) but from that

genus it differs by the perithecia having an ostiole and by the asci being fusoid rather than globose or subglobose. It should be noted that *Samarospora* is also an aquatic species which grows on *Potamogeton.*

Samarosporella pelagica Linder, sp. nov.

Plate III, figs. 1–4.

Peritheciis nigris, solitariis et sparsis, carbonaceis, in substrato immersis, subglobosis, plus minusve 170 μ crassitudine, 195 μ altitudine, ostiolatis; ostiolis papilliformibus et paullulum exsertis; ascis fusoideis, apicibus rotundatis instructis, 140–165 x 25–30 μ, deliquescentibus; ascosporis 4–8, hyalinis, elongato-ellipsoideis vel nonnihil fusoideis, alatis, (18)–25–30–(39.5) x 7.5–10.5–(11.5) μ alis exclusis; ascosporis abortivis non alatis, 15–20 x 7–8 μ.

Perithecia black, solitary and distantly scattered, carbonaceous, immersed in the substratum, subglobose or globose ± 170 μ thick, 195 μ in height, ostiolate. The ostiole papillate or somewhat flattened above, slightly exserted. The **asci** fusoid, somewhat rostrate with a rounded apex, 140–165 x 25–30 μ, deliquescing as the spores mature. **Ascospores** 4–8 in the ascus, usually some of them aborted, hyaline, elongate-ellipsoid or somewhat fusoid, (18)–25–30–(39.5) x 7.5–10.5–(11.5) μ, excluding the hyaline wings which are somewhat undulate and of irregular width; the aborted ascospores not winged or the wings vestigial, ellipsoid, 15–20 x 7–8 μ.

Specimen examined: **Massachusetts,** Provincetown, on driftwood covered by eight feet of water at high tide, July 24, 1943, *E. S. Barghoorn, 18.* **Type.**

DIDYMOSPORAE

Ceriosporopsis Linder, gen. nov.

Peritheciis nigris (atro-brunneis sub microscopio), membranaceis et collabescentibus siccando, plerumque in substrato immersis, substrato attrito autem superficialibus, ovoideis vel elongato-ellipsoideis, ostiolatis, ostiolis excentricis, rotundato-conicis vel papilliformibus; paraphysibus absentibus; ascis non visis, sed octo-ascosporis frequenter coacervatis; ascosporis hyalinis vel dilute coloratis, ellipsoideis, uniseptatis et ad apices ambos appendiculatis; appendiculis hyalinis, robustis fastigatisque demum dehiscentibus vel deliquescentibus qua ex re sporae demum utrinque truncatae sunt.

Perithecia black, or dark brown under the microscope, membranous and collapsing on drying, mostly buried in the substratum but becoming exposed by erosion of the decayed wood, ovoid to elongate-ellipsoid, ostiolate; the ostiole eccentric, rounded-conoid or papilliform. **Paraphyses** absent. **Asci** not seen but probably 8-spored since the spores occur frequently in bundles of eight. **Ascospores** hyaline or dilutely colored, two-celled and with a stout hyaline and tapering elongate appendage at each end, the appendages dehiscent or deliquescent and then the ascospores are truncate at each end.

This genus strongly resembles *Ceriospora* but differs by the irregular shape of the membranous, collapsing perithecia, the deliquescent asci, and the deliquescent appendages of the ascospores. In view of the fact that the asci of this species soon deliquesce, Saccardo and Marchal (Rev.

Myc. **7**: 148. 1885) may have misinterpreted their genus *Tiarospora* when they placed it in the Sphaeropsidales and the spores that were described as conidia of the imperfect genus were actually liberated by the early dissolution of the ascus wall. That the spores of *Ceriosporopsis* are ascospores is clearly indicated by the frequent occurrence of the spores in clusters of eight and by the fact that in neither of the appendages is there any evidence of a canal that would indicate connection with a conidiophore. The genus appears, because of the structure of the wall and the nature of the spores, to be related to *Bombardia* or to the Sordariaceae.

Ceriosporopsis halima Linder, sp. nov.

Plate III, figs. 10–12.

Peritheciis nigris vel sub microscopio atro-brunneis, membranaceis, plerumque in substrato immersis vel substrato attrito superficialibus, ovoideis vel elongato-ellipsoideis, axi longiora superficie substrati parallelo, 175–400 x 90–300 μ, ostiolatis; ostiolis excentricis, rotundato-conicis vel papilliformibus; ascis non visis; ascosporis hyalinis vel dilute coloratis, uniseptatis et ad apices ambos appendiculatis, 22.5–26–(35) x 8–10 μ appendiculis exclusis, appendiculis hyalinis, robustis fastigatisque 14–20 x 5–7 μ, demum dehiscentibus vel deliquescentibus, qua ex re sporae truncatae sunt.

Perithecia black to the naked eye or dark brown under the microscope, membranous, buried in the substratum or becoming superficial through the erosion of the matrix, ovoid to elongate-ellipsoid, variable in shape and size, 175–400 x 90–300 μ, the long axis parallel to the surface of the substratum; the ostiole conspicuous, rounded-conoid or papillate, eccentric. **Ascospores** ellipsoid, hyaline or very dilutely colored, 22.5–26–(35) x 8–10 μ, 2-celled, each cell usually with a single large vacuole, with stout hyaline, tapering, straight or curved appendages at each end, the appendages somewhat gelatinized and either deliquescent or dehiscent.

Specimens examined: **New Hampshire,** Portsmouth, on test block below water at all times, immersed Dec. 29, 1941, removed Aug. 25, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 11;* **Massachusetts,** Newburyport, on test board in brackish water, submerged May 25, 1942, and removed Oct. 16, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 19a;* **Connecticut,** Saybrook, on test block below water at all times, immersed Dec. 19, 1941, removed Aug. 25, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 17.* **Type.**

Dr. Barghoorn has found by single spore culture that this species is the ascigerous stage of *Helicoma salinum* which is described in the present paper among the Fungi Imperfecti.

Remispora Linder, gen. nov.

Peritheciis solitariis vel nonnihil gregariis, in substrato immersis, dilute coloratis cremeis vel isabellinis, membranaceis, subglobosis, conspicue ostiolatis, ostiolis truncato-conicis, eccentricis; paraphysibus absentibus; ascis late fusoideis nonnihil apiculatis, 3–8 sporas efferentibus. Ascosporis ovoideis, ellipsoideis vel elongato-ellipsoideis, hyalinis, uniseptatis, ad apicem utrumque bi-appendiculatis; appendiculis subgelatinosis divergentibusque.

Perithecia solitary or somewhat gregarious, imbedded in the substratum, light colored, about isabellinous or cream-colored, subglobose,

membranous and with a pronounced truncate-conoid, eccentric ostiole. **Paraphyses** absent. **Asci** broadly fusoid with a slight apiculus, tardily deliquescent, 3–8-spored, usually with some of the spores aborted. **Ascospores** ovoid, ellipsoid or elongate-ellipsoid, hyaline, 1-septate, with two hyaline, broad and tapering subgelatinous appendages at each end, the appendages diverging and nearly at right-angles to the long axis of the spore, and later deliquescing or dropping off.

This genus is characterized by the mustache-shaped appendages at each end of the two-celled spores, and these with the light-colored, membranous perithecial wall, seem ample to segregate the species from *Massarinula*. It seems probable that the appendages serve, at least temporarily, as a means of keeping the spores suspended in the water and hence assist in the dispersal of the species. The name is derived from *remus* = oar, and *spora*.

Remispora maritima Linder, sp. nov.

Plate III, figs. 5–9.

Peritheciis solitariis vel subgregariis, in substrato immersis, cremeis vel isabellinis, membranaceis, subglobosis, 230–500 x 225–500 μ; ostiolis truncato-conicis, excentricis; ascis late fusoideis et nonnihil apiculatis, 48–65 x 12–20 μ, ascosporas 3–8 gerentibus; ascosporis ovoideis, ellipsoideis vel elongato-ellipsoideis, hyalinis, uniseptatis, ad septa non constrictis, (17.5)–21.5–27–(31.5) x (8)–10–11.5–(12) μ appendiculis exclusis, ad apicem utrumque bi-appendiculatis, subgelatinosis, fastigatis, divergentibus.

Perithecia solitary or somewhat gregarious, immersed in the substratum, cream colored or isabellinous, membranous and collapsing on drying, subglobose, 230–500 x 225–500 μ, with a truncate, conoid, and eccentric or nearly lateral ostiole. **Asci** broadly fusoid and somewhat apiculate, tardily deliquescent, 48–65 x 12–20 μ. **Ascospores** 3–8 per ascus, not infrequently some of them aborted, ovoid, ellipsoid, or elongate-ellipsoid, hyaline, 1-septate, not constricted at the septum, (17.5)–21.5–27–(31.5) x (8)–10–11.5–(12) μ excluding the appendages; appendages in pairs at each end, stout and tapering, somewhat gelatinous, divergent and somewhat recurved so that they are approximately at right angles to the long axis of the spore.

Specimens examined: **Maine,** Thomaston, on back board for test blocks below water at all times, immersed Sept. 1938, removed Nov. 27, 1942, *W. F. Clapp*, comm. *E. S. Barghoorn, 22B;* **Massachusetts,** Provincetown, jetty bulkhead of breakwall three feet above low tide level, built 1900–01, removed Sept. 24, 1942; Provincetown, on driftwood two feet above low tide level, Sept. 24, 1942, *E. S. Barghoorn, 29.* **Type.**

Unlike most appendiculate species described in this paper, the appendages of this one appear not to be secondary formations, but rather seem to be remnants of the ascus protoplasm that in some way have been differentiated during the formation of the spores. When the spores are mounted in acid-fuchsin lactophenol and examined under the oil immersion lens, definite striae may be seen, as may also remnants of the undifferentiated ascus protoplasm (plate III, 9b.).

Amphisphaeria maritima Linder, sp. nov.

Plate III, figs. 13–16.

Peritheciis nigris, carbonaceis, subsphaericis vel late rotundatis et nonnihil conicis, usque ad 200 μ diametro, superficialibus vel partim immersis; ascis cylindricis, 54.5–60 x 8–13 μ, octosporis, distichis; ascosporis brunneis, uniseptatis, ad septa leniter vel haud constrictis, 16.5 x 5 μ.

Perithecia black and carbonaceous, subspherical or broadly rounded and conical, up to 200 μ in diameter, ostiolate, superficial or else only partly immersed in the substratum. **Asci** cylindrical with the apical wall somewhat thickened, 54.5–60 x 8–13 μ, 8-spored, distichous. **Ascospores** brown, uniseptate, not or only slightly constricted at the septa, 16.5 x 5 μ.

Specimens examined: **Maine,** Bucksport, on test block below water at all times, immersed Dec. 19, 1941, removed Aug. 25, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 13;* **Massachusetts,** Woods Hole, on test block seven to eight feet below low tide level, immersed Oct. 13, 1941, removed June 13, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 3a.* **Type.**

Lentescospora Linder, gen. nov.

Peritheciis solitariis vel sparsis, membranaceis et collabescentibus siccando, nigris vel sub microscopio atro-brunneis, ovoideis vel subcylindraceis, minute ostiolatis; paraphysibus absentibus; ascis non visis sed probabiliter deliquescentibus maturitate; ascosporis hyalinis, ellipsoideis vel elongato-ellipsoideis, 0- vel 1-septatis, raro 2-septatis et ad septa leniter constrictis, parietibus ad apices ambos incrassatis et subgelatinosis.

Perithecia solitary or scattered, membranous and collapsing on drying, black to the naked eye or dark brown under the microscope, ovoid to subcylindrical, with a minute papillate ostiole. **Paraphyses** absent. **Asci** not seen and are probably soon deliquescent. **Ascospores** hyaline, ellipsoid or elongate-ellipsoid, 0- or 1-septate, rarely 2-septate, somewhat constricted at the septa, the walls of the ends of the spores thickened and somewhat gelatinized.

It is probable that this genus is closely related to both *Ceriosporopsis* and to *Remispora* since the perithecia of all are membranous and collapsing, and the spores are hyaline, two-celled, and with modified appendages, although in this genus the appendages may be considered as being reduced to a mere thickening and gelatinization of the apical walls of the spores (Pl. IV, fig. 3). The ostiolar neck is much reduced and consists of one or two rows of cells arranged vertically around the opening of the perithecium (Pl. IV, fig. 2). These differences, in the light of our present incomplete knowledge of related forms, seem to warrant the erection of the above described genus, the name of which is derived from *lentesco* = to stick (referring to the gelatinized apices of the spores) and *spora.*

Lentescospora submarina Linder, sp. nov.

Plate IV, figs. 1–3.

Peritheciis solitariis vel sparsis, membranaceis et collabescentibus siccando, nigris, sub microscopio autem atro-brunneis, ovoideis vel subcylindraceis, 225–320 x 80–130 μ,

ostiolis exiguis, papillatis et supra substratum paullo exsertis; ascosporis hyalinis, ellipsoideis vel elongato-ellipsoideis, 23–28 x 6–10 μ, 0- vel 1-septatis, raro 2-septatis et ad septa leniter constrictis, parietibus ad apices ambos incrassatis et subgelatinosis.

Perithecia solitary or scattered, membranous and collapsing on drying, black to the naked eye but dark brown under the microscope, ovoid to subcylindrical, 225–320 x 80–130 μ, with a minute, papillate, central and scarcely exserted ostiole. **Ascospores** hyaline, ellipsoid or elongate ellipsoid, 23–28 x 6–10 μ, 0- or 1-septate, rarely 2-septate, somewhat constricted at the septa, apical walls of one, or most frequently both ends of the spores, thickened and somewhat gelatinized.

Specimen examined: **Connecticut,** Bridgeport, on test board submerged at all times, immersed Dec. 3, 1941, removed Dec. 21, 1942, *W. E. Clapp,* comm. *E. S. Barghoorn, 30.* **Type.**

Halosphaeria Linder, gen. nov.

Peritheciis solitariis vel subgregariis, immersis, ovoideis, membranaceis, superne atro-fuscis vel subnigris, infra subhyalinis, ostiolatis; ostiolis excentricis et obliquis, atris, crassis et breviter cylindricis; paraphysibus absentibus; ascis late clavatis; ascosporis quattuor, ellipsoideis, hyalinis, bi-cellulatis, cellula quaque vacuola unica magna instructa, sporis ad septum leniter vel haud constrictis tribusque appendiculis hyalinis, gracilibus ornatis quarum duae vulgo ad septum unaque frequenter ad unum apicem nascuntur.

Perithecia solitary or subgregarious, immersed in the substratum, ovoid, membranous, dark fuscous or nearly black above; subhyaline below, ostiolate; the ostiole eccentric and oblique, black, stout and short-cylindrical. **Paraphyses** absent. **Asci** 4-spored, broadly clavate. **Ascospores** ellipsoid, hyaline, two-celled, each cell usually with a single large conspicuous vacuole, the spores not or only slightly constricted at the septum and provided with (2)–3–(4) slender hyaline appendages of which two are usually at the septum and one at one end.

Halosphaeria appendiculata Linder, sp. nov.

Plate IV, figs. 4–7.

Peritheciis solitariis vel subgregariis, immersis, ovoideis, membranaceis, superne atro-fuscis vel fuligineo-atris, infra subhyalinis, 425–500 x 317–330 μ, ostiolatis; ostiolis excentricis obliquisque, atris, crassis et breviter cylindricis; ascis 4-sporis, late clavatis, plus minusve 55 x 18.5 μ; ascosporis ellipsoideis, 25–29 x 9–12 μ, hyalinis, 2-cellulatis, cellula utraque vacuola simplici magna conspicuaque instructa, sporis non vel leniter constrictis ad septum tribusque appendiculis hyalinis gracilibus ornatis quarum duae vulgo ad septum unaque frequenter ad unum apicem nascuntur, appendice terminali interdum nulla.

Perithecia solitary or subgregarious, immersed in the substratum, ovoid, membranous, dark fuscous to nearly black above, shading to subhyaline below, 425–500 x 317–330 μ, ostiolate; the ostiole eccentric and oblique, black, stout and short-cylindrical. **Asci** 4-spored, broadly clavate, ± 55 x 18.5 μ. **Ascospores** ellipsoid, 25–29 x 9–12 μ, hyaline, two-celled, each cell with a large conspicuous vacuole, the spores not or but slightly constricted at the septum and provided with (2)–3–(4) slender, hyaline, tapering appendages, 11–15 x 1–1.5 μ, of which two are usually at the septum and one at one end of the spora or occasionally the terminal appendage may be lacking.

Specimen examined: **Massachusetts,** Newburyport, on test board in brackish water, below low water at all times, submerged May 25, 1942, removed Oct. 16, 1942, *W. F. Clapp,* comm. *E. S. Barghoorn, 19c.* **Type.**

PHRAGMOSPORAE

Leptosphaeria orae-maris Linder, sp. nov.

Plate IV, figs. 8–11.

Peritheciis solitariis vel subgregariis, immersis, late ovoideis vel subglobosis, membranaceis, superne aterrime fuscis vel atris, ad latus inferum pallescentibus, 160–240 μ longitudine, 140–200 μ latitudine, 125–200 μ altitudine, ostiolatis; ostiolis atris, brevibus, papillatis, leniter exsertis ultra substratum; paraphysibus ramosis, hyalinis, interdum anastomosantibus, longitudine variabili sed longioribus ascis, 1–1.5 μ diametro; ascis clavatis, primum crasso-tunicatis deinde tenui-tunicatis, octosporis, distichis, parte sporogena 58 μ longa et 8–10 μ lata; ascosporis late fuscoideis, fuscis, 1-septatis, tarde 3-septatis, constrictis ad septum centrale, parietibus levibus vel subasperulatis, 18–22 x 5–6.5 μ.

Perithecia solitary or subgregarious, immersed in the substratum, broadly ovoid to subglobose, membranous, very dark brown or black above and becoming lighter colored below, 160–240 μ long, 140–220 μ wide, 125–200 μ high, ostiolate; the ostiole black, short, papillate and slightly exserted beyond the substratum. **Paraphyses** hyaline, branched and occasionally anastomosing, of variable length but exceeding the length of the asci, 1–1.5 μ in diameter. **Ascus** clavate, at first thick-walled but later becoming thin-walled, 8-spored, distichous, the sporogenous part 58 x 8–10 μ. **Ascospores** broadly fusoid, brown, 1-septate, tardily becoming 3-septate, constricted at the middle septum, the wall smooth to asperulate, 18–22 x 5–6.5 μ.

Specimen examined: **California,** Long Beach, on driftwood, Feb. 1943, *V. G. Dethier (B).* **Type.**

Cooke and Plowright (Grevillea **5:** 120. 1877.) described *Sphaeria maritima,* later transferred to *Leptosphaeria* by Saccardo (Syll. Fung. **2:** 73. 1883) as occurring on *Juncus maritima.* Because of its habitat, there was the possibility that this might be the same as the present species, but instead, the spores proved to be 5-septate and yellowish rather than tardily 3-septate and brown. *Leptosphaeria muralis* Sacc., not from a marine habitat, in general appearance seems to be closely related to this species but the perithecia are entirely black and the spores are smaller.

Sphaerulina orae-maris Linder, sp. nov.

Plate IV, figs. 12–15.

Peritheciis solitariis vel sparsis, membranaceis, partim immersis, atro-fuscis vel subatris superne, dilute fuscis infera in parte, globosis vel subglobosis, 200 μ cc. diametro; ascis clavatis, tristichis, 72 x 10–14 μ; ascosporis 8, fusoideis utrinque obtusatis, inaequilateralibus, hyalinis, 3-septatis, haud vel leniter constrictis ad septa, parietibus levibus, 26–30 x 5–6.5 μ.

Perithecia solitary or scattered, membranous, partially immersed in the substratum, subglobose or globose, dark brown or nearly black above, becoming light fuscous below, approximately 200 μ in diameter. **Para-**

physes lacking. **Asci** clavate, tristichous, 72 x 10–14 μ. **Ascospores** 8, fusoid and bluntly rounded at both ends, inequilateral, hyaline, 3-septate, not or only slightly constricted at the septa, with smooth walls, 26–30 x 5–6.5 μ.

Specimen examined: **California,** Long Beach, on driftwood, Feb. 1943, *V. G. Dethier.* **Type.**

Peritrichospora Linder, gen. nov.

Peritheciis solitariis vel sparsis, majorem ad partem immersis, globosis, carbonaceis, nigris, ostiolatis; ostiolis minutissimis, papillatis, apicalibus; paraphysibus absentibus; ascis fusoideis vel late fusoideis; ascosporis 8, fusoideis, biappendiculatis, hyalinis, fuscis circum septum centrale, aut quinque-septatis aut 1-septatis, atque 1–3 pseudo-septis additis ad utrumque latus, multi-crinitis circum septum centrale, appendicibus terminalibus hyalinis, subcylindricis, apicibus obtusis.

Perithecia solitary or scattered, for the most part immersed in the substratum, globose, carbonaceous, black, ostiolate; the ostiole extremely small and papillate, central. **Paraphyses** absent. **Asci** fusoid or broadly fusoid. **Ascospores** 8, fusoid, biappendiculate, hyaline but becoming brownish around the central septum, either 5-septate or 1-septate with 1–3 pseudosepta on each side of the septum, polytrichous around the septum; the terminal appendages hyaline, subcylindrical and with obtuse apices.

This genus may readily be separated from others that have hitherto been described by the numerous cilium-like appendages around the central septum and by the carbonaceous spherical perithecia which have proportionately very small ostioles.

Peritrichospora integra Linder, sp. nov.

Plate V, figs. 6–9.

Peritheciis solitariis vel sparsis, majorem ad partem immersis, globosis, 225–260 μ diametro, nigris, ostiolatis; ostiolis minutissimis, papillatis, apicalibus; ascis fusoideis vel late fusoideis, 82–140 x 25–30 μ; ascosporis 8, fusoideis, biappendiculatis, hyalinis, fuscis circum septum unicum centrale, pseudo-septis 2–6, multi-crinitis circum septum centrale, crinibus haud longioribus dimidio ascosporae, cc. ¾ μ diametro ad basin, sporis (appendicibus exclusis) 21.5–33 x 6.5–8.3 μ, appendicibus terminalibus hyalinis, subcylindricis, 10–13.5 μ longis, apicibus obtusis.

Perithecia solitary or scattered, partially immersed in the substratum, globose, 225–260 μ in diameter, black, ostiolate; the ostioles very small and papillate, apical. **Asci** fusoid or broadly fusoid, 82–140 x 25–30 μ. **Ascospores** hyaline, 8, fusoid, with an elongate, 10–13.5 μ long, hyaline, subcylindrical appendage at each end, 1-septate and with numerous cilium-like appendages just above and below the septum, the cilium-like appendages about half the length of the spore.

Specimen examined: **Massachusetts,** Woods Hole, on test board below water at all times, immersed Mar. 6, 1941, removed Aug. 25, 1942. *W. F. Clapp,* comm. *E. S. Barghoorn, 10.* **Type.**

Peritrichospora lacera Linder, sp. nov.

Plate V, figs. 1–5.

Peritheciis solitariis vel sparsis, majorem ad partem immersis, globosis, plus minusve 338 μ diametro, nigris, ostiolatis; ostiolis minutissimis, papillatis, apicalibus; ascis fusoideis vel late fusoideis, plus minusve 75 x 22 μ; ascosporis 8, fusoideis, biappendiculatis, hyalinis, fuscis circum septum centrale, 5-septatis, tarde multi-crinitis circum septum centrale, crinibus haud longioribus cellula unica, cc. ¾ μ diametro ad basin, sporis (appendicibus exclusis) 41–53–(62.8) x 11.5–15 μ, appendicibus terminalibus hyalinis, subcylindricis, 9.5–16.5–(21.5) μ longitudine, 3.3–4 μ diametro ad basin, 1.75 μ diametro ad apicem obtusum.

Perithecia solitary or scattered, about ⅔ immersed in the substratum, globose, ± 338 μ in diameter, black, ostiolate; ostioles very small and scarcely papillate, apical. **Asci** fusoid or broadly fusoid, ± 75 x 22 μ. **Ascospores** 8 in the ascus, fusoid, biappendiculate, hyaline, brownish around the middle septum, 5-septate and tardily becoming polytrichous around the central septum, the cilium-like appendages about equalling the length of the spore cell and approximately ¾–1 μ in diameter at the base, the spores (excluding the appendages) 41–53–(62.8) x 11.5–15 μ, the terminal appendages hyaline, subcylindrical, 9.5–16.5–(21.5) μ in length, 3.3–4 μ in diameter at the base, 1.75 μ in diameter at the obtuse apex.

Specimen examined: **Massachusetts,** Provincetown, on driftwood, two feet above the low tide level, Sept. 24, 1942, *E. S. Barghoorn, 28b.* **Type.**

This species differs from the preceding in that the ascospores even while within the ascus are clearly 5-septate, whereas in *P. integra*, the spores become 1-septate just before liberation from the ascus, and the two resulting cells then have pseudosepta or annular thickenings of the cytoplasm which indicate where septa may form, as they do when the spore germinates. This species, *P. lacera*, produces the lateral, cilium-like appendages only after the perispore (Pl. V, figs. 4–5) has been ruptured and shed, the perispore tearing at the first septum on either side of the central one and then peeling off the spore and appendage after the fashion that a glove is removed from the fingers of a person's hand.

SCOLECOSPOREAE

HALOPHIOBOLUS Linder, gen. nov.

Peritheciis solitariis vel gregariis, late ampulliformibus, elongato-ellipsoideis vel subcylindraceis, membranaceis vel subcarbonaceis, atris, fuscis, vel laete coloratis vel supra fuscis et infra laete coloratis; ostiolis conoideis vel elongato-cylindraceis et rectis vel undulatis; aparaphysatis, ascis clavatis vel elongato-clavatis, octosporis; ascosporis hyalinis, filiformibus, vulgo non septatis sed interdum pluriseptatis, ad extrema utraque appendicula hyalina, conoidea ornatis.

Perithecia solitary or gregarious, flask-shaped to elongate ellipsoid or subcylindrical, membranous to subcarbonaceous, black, fuscous or light colored, the perithecia often dark above and light colored below; the ostiole conical to elongate and cylindrical, straight or undulate, deep fuscous or black. **Paraphyses** absent. **Asci** elongate-clavate, 8-spored. **Ascospores** hyaline, elongate and slender, cylindrical or filamentous,

mostly non-septate at first and only becoming septate on germination (one species 15–18-septate), provided at each end with a conspicuous hyaline, conoid, or somewhat inflated and conoid appendage.

As the name implies, this genus, which resembles *Ophiobolus*, has to date been collected only in marine habitats. It is distinguished from *Ophiobolus* by the lack of paraphyses, by the predominantly membranous perithecia, and by the characteristic hyaline appendage at each end of the ascospore. The appendages, as already mentioned in the introduction, have an adhesive quality which enables the spores to become attached to the substratum.

KEY TO THE SPECIES OF HALOPHIOBOLUS

A. Neck of ostiole longer than the height of the perithecium.
  B. Ascospores 74–82.5 μ long; perithecia cylindrical and paralleling the surface of the substratum ..... **1. H. cylindricus**
  BB. Ascospores more than 100 μ long.
    C. Perithecial walls black, opaque, 11.5–21.5 μ thick; perithecia imbedded or superficial ..... **2. H. opacus**
    CC. Perithecial walls subhyaline or light fuscous, (15)–16.5–30 μ thick; perithecia imbedded ..... **3. H. longirostris**
AA. Neck of ostiole shorter than the height of the perithecium.
  D. Ascospores 15–18-septate and breaking into uniseptate segments. On *Zostera marina* ..... **4. H. maritimus**
  DD. Ascospores at most pseudoseptate or only becoming septate on germination.
    E. Tips of ascospores suddenly inflated and rounded-truncate; appendage inflated and tapering to a slender flanged beak; on buried leaf-sheaths of *Spartina* ..... **5. H. medusa**
    EE. Tips of ascospores rounded or truncate, not inflated; appendages conoid or elongate conoid.
      F. Perithecial walls thick, blackish brown. On *Zostera marina*. **6. H. halimus**
      FF. Perithecial walls dark near the surface of the substratum, nearly hyaline below and only tardily becoming black ..... **7. H. salinus**

The type species is *Halophiobolus opacus*.

1. Halophiobolus cylindricus Linder, sp. nov.

Plate VI, figs. 12–14.

Peritheciis immersis, cylindraceis vel subcylindraceis et parallelis superficie substrati, plus minusve 762 x 123 μ, sub microscopio fuscis, membranaceis, cellulis extremorum duorum subquadratis vel angulatis, cellulis ceteris elongato-rectangulatis; ostiolis atris, cylindricis, usque ad 550 μ longitudine, 24–27 μ diametro, plectenchymaticis, ad basem bulboso-amplificatis, pseudoparenchymaticis et 50–57 μ diametro; ascis deliquescentibus; ascosporis breviter filiformibus, hyalinis, curvatis vel nonnihil spiraliter tortis, ad extrema utraque appendice hyalina, elongato-conoidea, 8.5–15 μ longitudine ornatis.

Perithecia immersed in the substratum, cylindrical or subcylindrical, averaging around 762 x 123 μ, fuscous under the microscope, membranous, the cells at the two ends and around the swollen base of the ostiolar neck subquadrate or angular (pseudoparenchymatous), the remaining cells elongate rectangular or subcylindrical; the ostiole black, cylindrical, up

to 550 μ long, 24–27 μ in diameter, plectenchymatous, arising from a bulbous pseudoparenchymatous base 50–57 μ in diameter. **Asci** soon deliquescing and leaving the spores in clusters of eight. **Ascospores** short filiform, hyaline, curved or somewhat spirally twisted, 74–82.5 x 5 μ, terminated at each end by a hyaline, elongate-conoid appendage, 8.5–11.5 μ long.

Specimens examined: **Massachusetts,** Provincetown Harbor, on upper portion of stump, Sept. 24, 1942, *E. S. Barghoorn, 23.* **Type.**

This species, like the following one, is reminiscent of *Linospora* and *Robergea* in that the asci, as shown by the fascicle of ascospores, parallel the long axis of the perithecium, but the perithecia being without a clypeus separates this species from the former genus, and lacking paraphyses, it is excluded from the latter.

2. Halophiobolus opacus Linder, sp. nov.

Plate VI, figs. 1–5.

Peritheciis immersis vel erumpentibus, atris, subsphaericis vel ovoideis, 198–264 x 148–214 μ (in substrato immersis ellipsoideis vel subcylindraceis et parallelis superficie substrati); ostiolis excentricis, cylindraceis vel nonnihil attenuatis, atris, usque ad 300 x 28–33 μ; parietibus peritheciorum 11.5–16.5–(21.5) μ crassitudine, strato intimo e cellulis hyalinis vel subfuscis consistente, parietibus tenuibus; strato medio crasso, pseudoparenchymatico, atro opacoque; strato externo hyphis elongatis subbullatis composito e quibus hyphae atrae tenues oriuntur et in substratum penetrant; ascis elongato-clavatis, curvatis, mox deliquescentibus; ascosporis filiformibus, rectis, curvatis, vel nonnihil spiraliter tortis, hyalinis, 155–190 x 3.3–4 μ, continuis, multivacuolatis, vel germinantibus 4–7 septatis, ad extrema utraque appendice hyalina, conoidea instructis, 7.5–8.5 μ longitudine.

Perithecia occurring singly or scattered, superficial or immersed, black, subglobose to ovoid, 198–264 x 148–214 μ or, when immersed in the substratum not infrequently cylindric-ellipsoid with the cylindrical or somewhat tapering, elongate ostiole arising from one end, the ostiole up to 300 x 28–33 μ; walls of the perithecium 11.5–16.5–(21.5) μ thick, the inner layer composed of thin-walled, subhyaline to light fuscous cells, the middle layer thick, pseudoparenchymatous and deep fuscous to black and opaque; the outer layer of rather closely interlaced and somewhat bullate hyphae which give rise to more slender dark hyphae that either ramify in the substratum or, in superficial specimens, form a loose, hairy covering. **Asci** when young are cylindric-clavate and curved, and at maturity soon deliquesce to liberate the eight ascospores. **Paraphyses** absent. **Ascospores** filiform, straight, curved, or somewhat spirally twisted, hyaline, 155–190 x 3.3–4 μ, non-septate and multivacuolate until germination when they may become 4–7-septate, ending in hyaline conoid appendages, 7.5–8.5 μ long.

Specimen examined: **Massachusetts,** Provincetown, on piling two feet above low tide level, July 24, 1942, *E. S. Barghoorn, 14.* **Type.**

In addition to the above perfect stage that was found occurring in nature, this fungus when grown on artificial media, produces chains of spores which may attain a length of 350–400 μ, the individual cells measuring (11.5)–16.5–21.5 x (8)–13–16.5 μ with the central cells larger than

the terminal. Occasionally the chains of cells are furcate at the base, rarely branched above. As a rule the cells are at first hyaline but with age they become brownish. These chains of spores have their counterpart within the agar as intercalary chains of varying length and in the natural substratum as single bladder-like cells or as short chains of two to five cells which are usually globose but when their diameter reaches the limit of size set by the diameter of the lumen of the tracheids, become elongate and ellipsoidal.

3. Halophiobolus longirostris Linder, sp. nov.

Plate VI, figs. 6–7.

Peritheciis semper in substrato immersis, solitariis, subhyalinis vel dilute fuscis, globosis vel late ellipsoideis, ostiolis mediis, atris, elongatis subrectis vel irregulariter curvatis, 594–700 x 41–58 μ; parietibus peritheciorum (15)–16.5–29.5 μ crassitudine; strue intima hyalina cellularum isodiametricarum compacte aggregatarum; strato medio crasso, hyalino, e cellulis aliquantulum rhomboideis efformato; strato externo tenui subhyalino vel dilute fusco, e cellulis cylindricis nonnihil bullatis consistente; ascis elongato-clavatis, mox deliquescentibus; ascosporis filiformibus, rectis, curvatis vel nonnihil spiraliter tortis, hyalinis, 155–200 x 3.3–4 μ, aseptatis, ad extrema utraque appendice hyalina, conoidea, 7–8.5 μ longitudine ornatis.

Perithecia always (?) immersed and occurring singly or scattered, subhyaline or dilute fuscous, globose or subellipsoid, the ostiole central, black, elongate, nearly straight or else somewhat geniculately bent as it penetrates to the outside of the woody substratum, 594–700 x 41–58 μ, the external hyphae here and there growing out into the cells of the wood and filling them with dark plectenchymatous hyphae; walls of the perithecium (15)–16.5–29.5 μ thick, the inner layer hyaline of closely aggregated nearly isodiametric cells with rich protoplasmic content, — the central layer thick, hyaline and composed of thin-walled, inflated, somewhat diamond-shaped cells, — the outer layer 1–2 cells thick and of slightly inflated, subhyaline to dilute fuscous subcylindrical cells among which are often enmeshed the crushed, discolored cells of the substratum. **Asci** when young cylindric-clavate, curved, at maturity soon deliquescing to leave the spores in bundles of eight. **Ascospores** filiform, straight, curved or somewhat spirally twisted, hyaline, 155–200 x 3.3–4 μ, nonseptate, terminated by a hyaline conoid appendage, 7.0–8.6 μ long at each end.

Specimen examined: **Maine,** below low tide level at all times, on test block immersed Sept., 1938, and removed Nov. 27, 1942, *W. F. Clapp,* communicated by *E. S. Barghoorn, 22.*

Older specimens, because of the darker color, resemble *H. opaca* described above. However, as shown in plate VI, figures 3 and 7, the structure of the perithecium wall of the two species is quite distinct, this species having large hyaline, diamond-shaped cells in the central layer, while *H. opaca* has a relatively thin, opaque black central layer.

Within the cells of the substratum, this species also produces bladder-like cells either singly or in short chains, their size being limited by the diameter of the lumen of the tracheids.

4. Halophiobolus maritimus (Sacc.) Linder, comb. nov.

Ophiobolus maritimus Saccardo, Syll. Fung. **2**: 350. 1883; Mounce, I. & W. W. Diehl. A new Ophiobolus on eelgrass. Canad. Journ. Res. **11**: 245. 1934.

This species was described as occurring on *Zostera marina* in the North Sea. The septation and segmentation of the ascospores distinguish it from other species of the genus.

5. Halophiobolus medusa (Ell. & Ev.) Linder, comb. nov.

Ophiobolus medusa Ellis & Everhart, Journ. Myc. **1**: 150. 1885; Mounce, I. & W. W. Diehl. Canad. Journ. Res. **11**: 243–245. *figs. 2, 6c-d.* 1934.

The species was described as growing on the buried leaf-sheaths of *Spartina* in New Jersey. The habitat would suggest that this fungus is also a salt or brackish water inhabitant, and like many of the other species mentioned in this paper, may well be a cellulose destroying form.

6. Halophiobolus halimus (Mounce & Diehl) Linder, comb. nov.

Ophiobolus halimus Mounce & Diehl. Canad. Journ. Res. **11**: 242–246. *figs. 1, 3–5, 6a–b, 7–9.* 1934.

Like *H. maritimus*, this species was found on *Zostera marina*, but in New Brunswick where it was thought to be a causative agent in the wasting disease of eelgrass. As stated in the introduction, the discovery of *Labyrinthula* over a more widespread area suggests that *H. maritimus* may be secondary or even saprophytic. At the same time, the need for further research on the rôle of this species in connection with wasting disease is indicated.

7. Halophiobolus salinus Linder, sp. nov.

Plate VI, figs. 8–11.

Peritheciis in matrice immersis vel substrato eroso liberatis, subglobosis vel late rotundate ampulliformibus, atris (fuscis sub microscopio) vel supra atris fuscisve, infra pallide fuscis, 275–300 μ diametro; ostiolis breviter et late conoideis vel papillatis; parietibus e cellulis amplis angulatis consistentibus; ascis primum fusoideis et ad apicem rotundatum attenuatis, deinde elongato-clavatis et mox deliquescentibus, octosporis; ascosporis hyalinis, filiformibus, curvatis vel nonnihil spiraliter tortis, 3.3 μ diametro in parte centrali, ad extrema attenuata 1.5 μ diametro, et utrinque appendice hyalina, conoidea, 7.5–8.5 μ longa ornatis.

Perithecia single or scattered, imbedded in the matrix or exposed by erosion of the surrounding decayed wood, membranous and collapsing on drying, subglobose to broadly rounded flask-shaped, black (fuscous under the microscope) or black above and dilute fuscous below, 275–300 μ in diameter; the ostiole short and broadly conoid or papillate; the walls of the perithecium composed of large, relatively thin-walled angular cells. **Asci** when young broadly fusoid and tapering to a rounded tip but when mature elongate-clavate and soon deliquescing to liberate the 8 ascospores. **Ascospores** hyaline, filiform, curved or slightly spirally twisted, 180–200 μ long, 3.3 μ diameter at the middle and tapering to 1.5 μ in diameter at the base of the hyaline, conoid appendages, 7.5–8.5 μ long which terminate either end of the spores.

Specimens examined: **New Hampshire**, Portsmouth, on test block four feet below low tide level, submerged Sept. 23, 1941, removed May 19, 1942, *W. F. Clapp*, communicated by *E. S. Barghoorn, 1d;* Portsmouth, on test block below water at all times, immersed Dec. 29, 1941, removed Aug. 25, 1942, *W. F. Clapp*, communicated by *E. S. Barghoorn, 11;* **Massachusetts,** Fall River, on test board eight feet below low water, immersed Feb. 1942, removed July 18, 1942, *W. F. Clapp*, communicated by *E. S. Barghoorn, 4;* Provincetown, on submerged stump three feet above low tide level, Sept. 24, 1942, *E. S. Barghoorn, 26;* Woods Hole, on manila rope in intertidal zone, *E. S. Barghoorn, 20;* **Connecticut,** Saybrook, on test board below low water level at all times, immersed May 1, 1942, removed Oct. 1, 1942, *W. F. Clapp*, communicated by *E. S. Barghoorn, 17.*

This species, perhaps the commonest of our eastern coast, strongly resembles *H. halimus* as regards the shape and size of the perithecia. However, it differs from that species by the color of the perithecial walls which only tardily become all dark, and by the shorter length of the ascospores which in *H. halimus are* 260–308 μ long.

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EXPLANATION OF PLATE I

All figures are drawn with the aid of a camera lucida. Each unit of scales B, C and E equals 10 μ; the unit of scale D equals 200 μ.

Figs. 1–3. *Diplodia orae-maris* Linder.

1. Pycnidium shown with the substratum dissected from one side. The upper surface is black and the lower surface is light colored. (× 25, scale D)
2. Characteristic hyaline conidiophores, one bearing an immature conidium, arising from the somewhat inflated cells that line the greater part of the interior of the pycnidium. (× 800, scale E)
3. A representative group of colored, two-celled pycnidiospores. (× 800, scale E)

Fig. 4. *Botryophialophora marina* Linder.

4. A portion of the repent or scandent mycelium bearing two clusters of phialides, each of which arises from a single basal cell. The globose conidia are produced semi-endogenously. (× 1000, scale C)

Figs. 5–6. *Orbimyces spectabilis* Linder.

5. Characteristic conidiophores anastomosing at the point where they cross and bearing above on a short hyaline sporogenous tooth the characteristic appendaged conidium. (× 425, scale B)
6. Two shining black conidia with their fuscous appendages. The lighter colored spot on the lower part of each conidium represents the place of attachment of the sporogenous teeth. (× 425, scale B)

Figs. 7–8. *Phialophorophoma litoralis* Linder.

7. A representative group of pycnidiospores. (× 1000, scale C)
8. Pycnidium shown with the substratum dissected from one side. The surface cells of the substratum have been darkened through the action of the fungus. (× 25, scale D)
9. Phialides, of which the middle one of the three right hand phialides is shown with a pycnidiospore escaping from the cup-shaped terminal portion. On left is shown a well developed phialophore bearing three phialides. (× 1000, scale C)

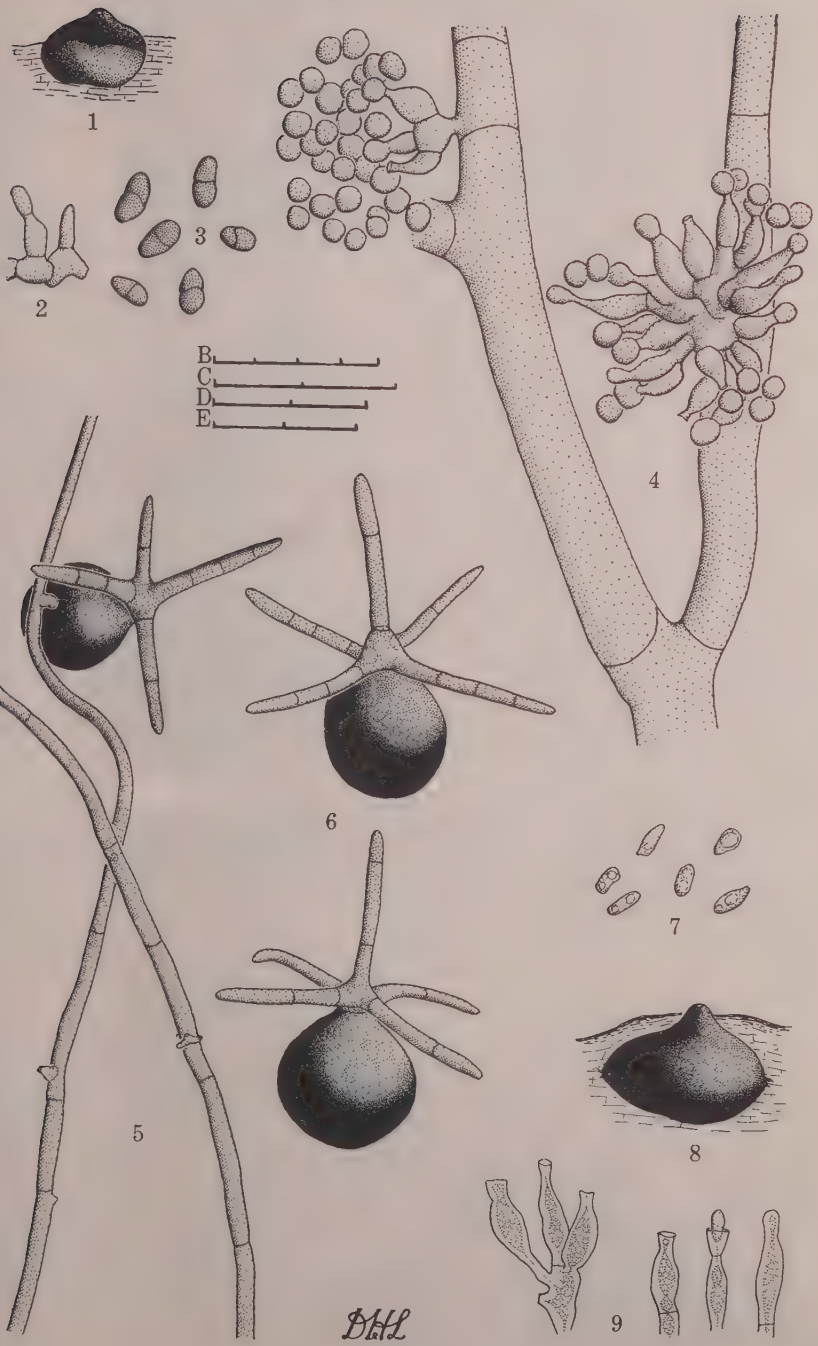


PLATE I

EXPLANATION OF PLATE II

All figures are drawn with the aid of a camera lucida, and are reproduced at a magnification of × 425. Each unit of the scale equals 10 μ.

Fig. 1. *Alternaria maritima* Sutherland.

1. a. The short, slightly colored, inconspicuous conidiophores bearing branching chains of conidia.
   b. Single conidium with an exceptionally long apical cell.

Figs. 2–6. *Helicoma maritimum* Linder.

Showing conidiophores and conidia and their variation in shape and dimensions. Fig. 6 depicts the more irregular type of conidium that is found in cultures while the remaining figures illustrate the more or less squarish outlines that appear more characteristic of the fungus as it occurs in nature.

Fig. 7. *Speira pelagica* Linder.

A group of four conidia, of which the upper right hand one illustrates the variation that may be observed in the older conidia.

Figs. 8–11. *Helicoma salinum* Linder.

Conidiophores and conidia drawn to show the variations of the fungus as it grows in culture. Fig. 11 shows the conidiophore with the dark, inflated terminal cell upon which the conidium is directly borne, a character that appears when the fungus is cultured on agar.

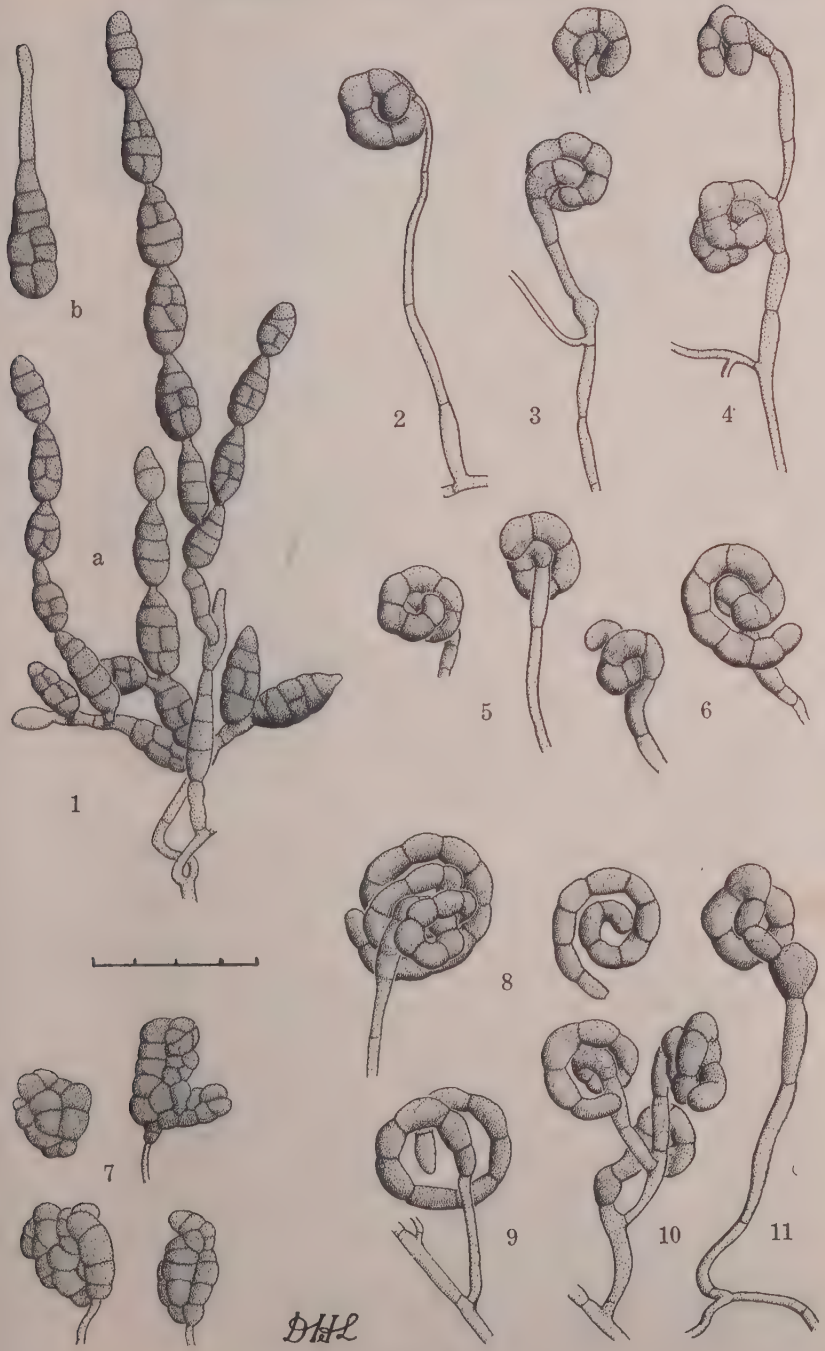


PLATE II

EXPLANATION OF PLATE III

All figures are drawn with the aid of a camera lucida. Each unit of scales A, B and C equals 10 μ; the unit of scale D equals 200 μ.

Figs. 1–4. *Samarosporella pelagica* Linder.

1. The globose, black, carbonous perithecium shown with half the substratum dissected away. (× 25, scale D)
2. Asci with ascospores nearly delimited but clearly showing one aborted spore (left), and an ascus with nearly mature ascospores (right). (× 350, scale A)
3. An abortive ascospore with an abortive wing. (× 1000, scale C)
4. Two ascospores showing variation in the size of the hyaline winged appendages. (× 1000, scale C)

Figs. 5–9. *Remispora maritima* Linder.

5. A subglobose, cream-colored perithecium showing the lateral position of the conoid ostiole which protrudes beyond the substratum. (× 25, scale D)
6. Three ascospores, of which the lowest one still retains the characteristic mustache-like hyaline appendage. (× 425, scale B)
7. An ascus with three differentiating spores, of which one is small and somewhat aborted. (× 425, scale B)
8. An ascus with mature ascospores. (× 425, scale B)
9. a. An ascospore with appendages still connected at the ends and including a remnant of the ascus protoplasm. (× 1000, scale C)
   b. An ascospore still showing remnants of the ascus protoplasm attached to the appendages. (× 1000, scale C)
   c. An ascospore with characteristic appendages. (× 1000, scale C)

Figs. 10–12. *Ceriosporopsis halima* Linder.

10. A black, elongate-ellipsoid perithecium dissected from the substratum. (× 25, scale D)
11. A group of four ascospores of which the two central ones have lost the deliquescent hyaline appendages. (× 425, scale B)
12. An ascospore shown at a greater magnification to illustrate the large central vacuoles. (× 1000, scale C)

Figs. 13–16. *Amphisphaeria maritima* Linder.

13. A nearly superficial perithecium as seen from above. (× 25, scale D)
14. Four dark-colored, uniseptate ascospores. (× 425, scale B)
15. An immature ascus showing the ascospores, already becoming septate, nearly differentiated. (× 425, scale B)
16. Two asci with distichously arranged ascospores. (× 425, scale B)

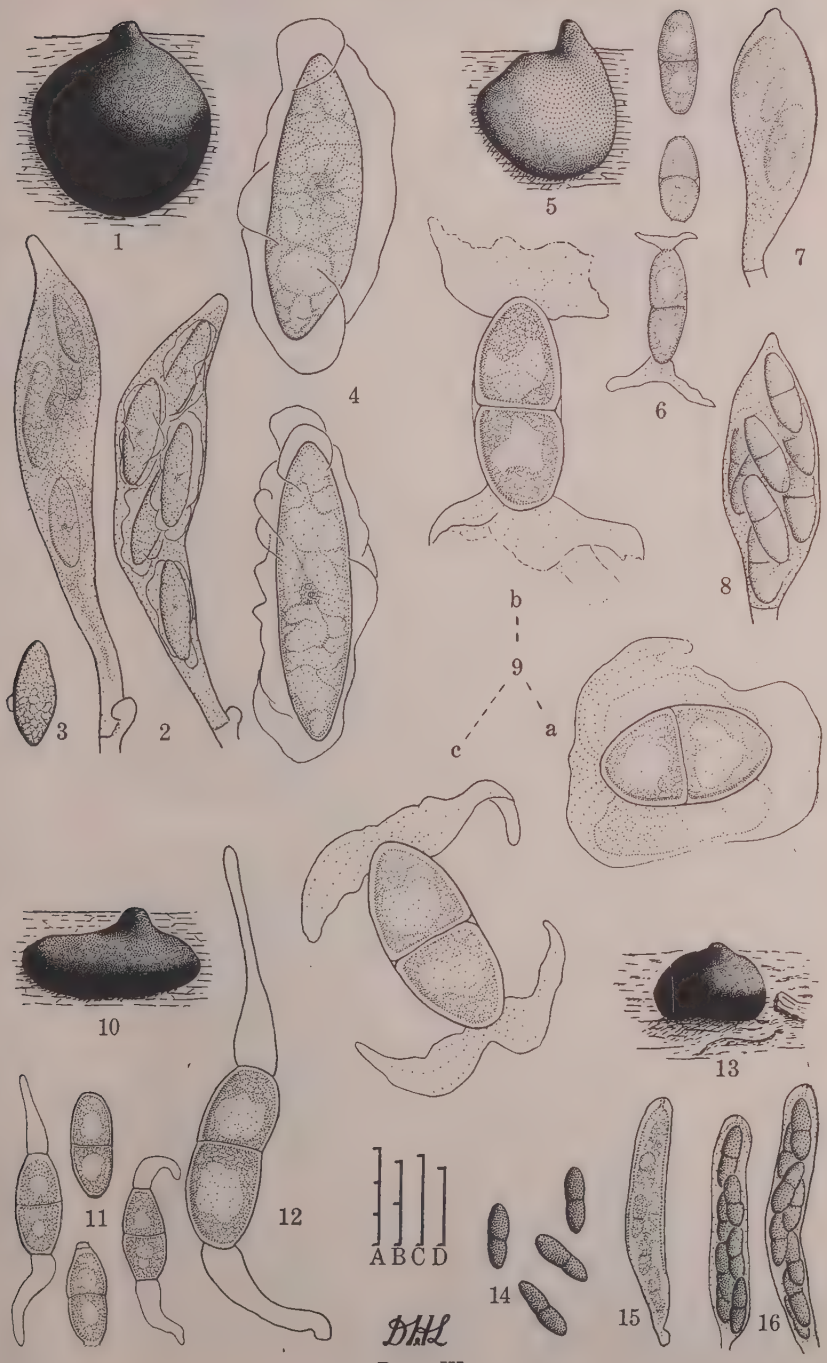


PLATE III

EXPLANATION OF PLATE IV

All figures are drawn with the aid of a camera lucida. Each unit of scales C and E equal 10 μ; the unit of scale D equals 200 μ.

Figs. 1–3. *Lentescospora submarina* Linder.

1. At the left, a perithecium partially exposed and showing its position in the substratum; at the right, a perithecium as seen from above. (× 25, scale D)
2. The ostiole and adjacent cells as seen from above. (× 800, scale E)
3. Four ascospores to illustrate variations in the shape, size, and the thickening of the apical walls. (× 800, scale E)

Figs. 4–7. *Halosphaeria appendiculata* Linder.

4. Two perithecia as seen from the side and the end, showing the blackened upper part and the lighter colored under portions. Note the stout, short-cylindrical and obliquely attached ostiole. (× 25, scale D)
5. Three ascospores to show the variation in number and attachment of the appendages. (× 800, scale E)

6–7. Mature and immature asci. (× 800, scale E)

Figs. 8–11. *Leptosphaeria orae-maris* Linder.

8. A broadly ovoid, immersed perithecium which is dark fuscous above and lighter colored below. (× 25, scale D)
9. A thick-walled immature ascus at the left and a thinner-walled mature ascus at the right containing 0- to 1-septate ascospores. (× 800, scale E)
10. Four ascospores with colored walls and with one to three septa. The septa in excess of the median one are usually formed after the spores are discharged from the ascus. (× 800, scale E)
11. A typical branched paraphysis. (× 800, scale E)

Figs. 12–15. *Sphaerulina orae-maris* Linder.

12. A partially imbedded perithecium, dark-colored where exposed and light-colored where buried in the substratum. (× 25, scale D)
13. A group of four ascospores. (× 1000, scale C)
14. A mature ascus with eight spores. (× 1000, scale C)
15. An immature ascus drawn to show the thickened wall. (× 1000, scale C)

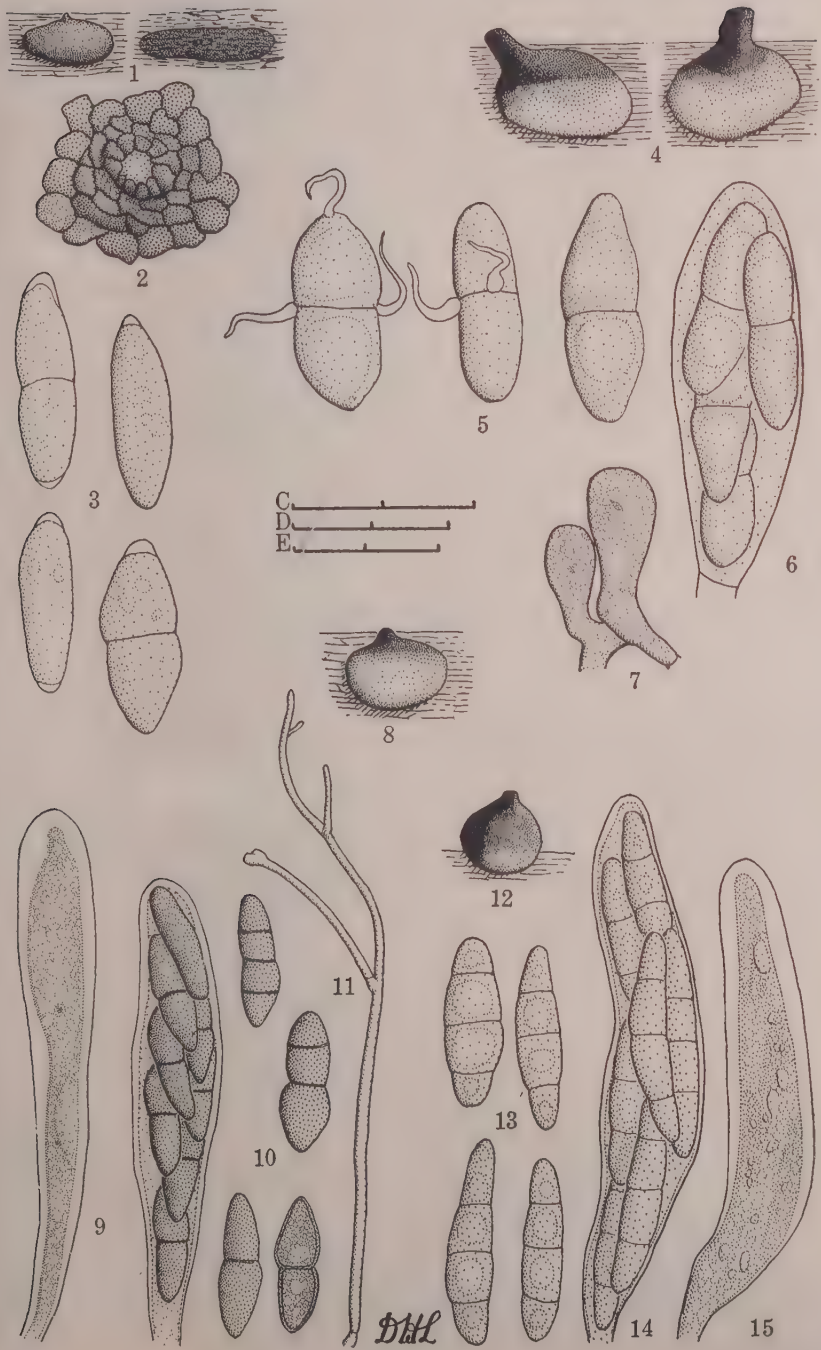


PLATE IV

EXPLANATION OF PLATE V

All figures are drawn with the aid of a camera lucida. Each unit of scales B and C equals 10 μ; the unit of scale D equals 200 μ.

Figs. 1–5. *Peritrichospora lacera* Linder.

1. A large subglobose, shining-black, carbonous perithecium which is partially buried in the substratum and which produces but a small inconspicuous ostiolar neck. (× 25, scale D)
2. A cluster of eight ascospores liberated by the dissolution of the ascus wall. (× 425, scale B)
3. Two ascospores, of which the right-hand one has just begun to form cilia around the central septum and the left-hand one with elongate and now more slender cilia. (× 425, scale B)

4–5. Young ascospores with the ruptured exospore which breaks away from the cells and peels off with the appendages making them appear longer than they actually are. These spores are younger than those shown in figure 3. (× 1000, scale C)

Figs. 6–9. *Peritrichospora integra* Linder.

6. A partially immersed, shining-black perithecium with the characteristic small ostiole. (× 25, scale D)
7. Two asci containing immature ascospores. The ascus on the left is the more mature. (× 1000, scale C)
8. Two uniseptate ascospores showing the coloring of the walls at the septa, the vacuolate cell contents that give the appearance of additional septa, and the long, hyaline appendages. (× 1000, scale C)
9. Conidial chains formed in culture. (× 425, scale B)

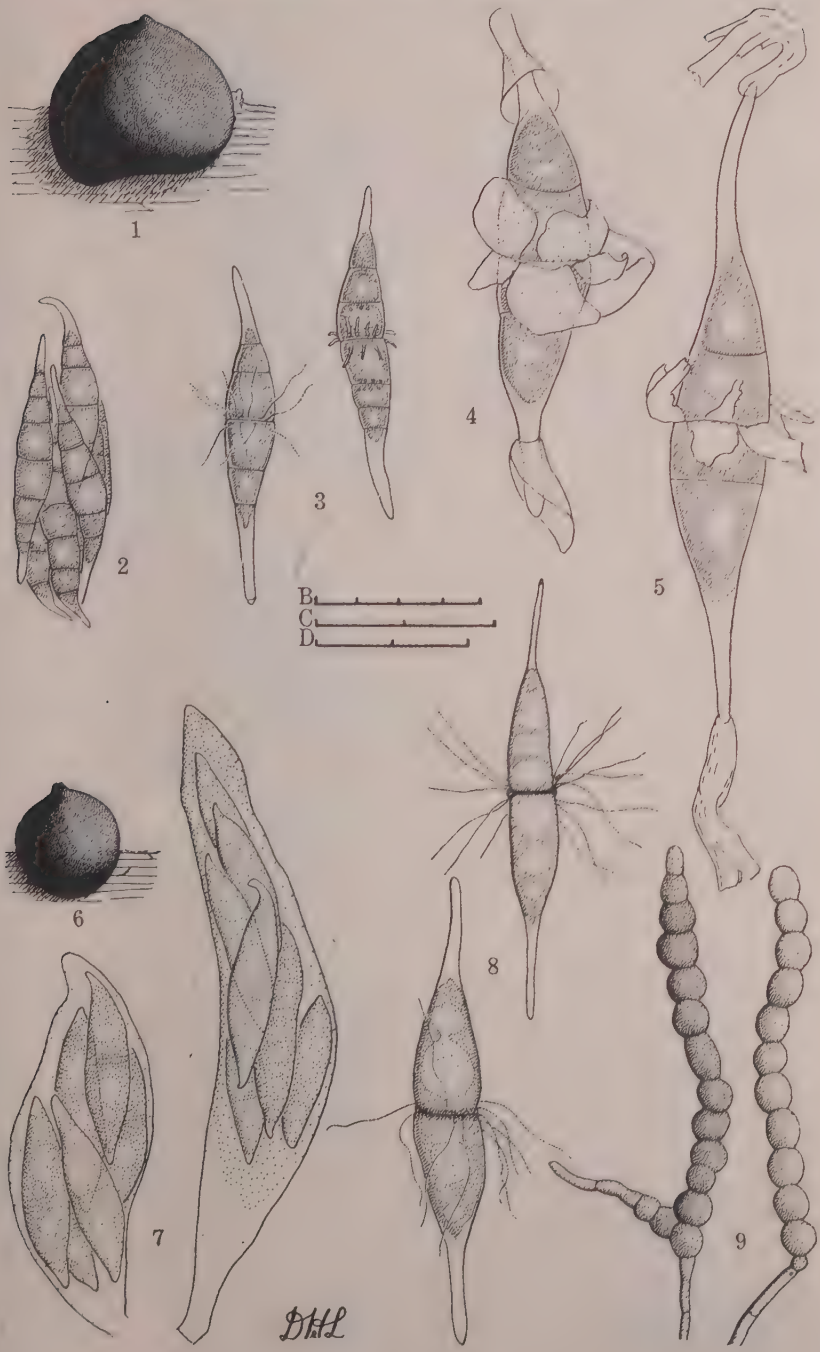


PLATE V

EXPLANATION OF PLATE VI

All figures are drawn with the aid of a camera lucida. Each unit of scales B and C equals 10 μ; the unit of scale D equals 200 μ.

Figs. 1–5. *Halophiobolus opacus* Linder.

1. Perithecium as seen in sectional view. The perithecium has become superficial through the erosion of outer portions of the substratum. (× 25, scale D)
2. A portion of the perithecial wall to show the black and nearly opaque middle layer bordered internally by elongate colored cells, and externally by the thin layer of cells which give rise to mycelium that normally penetrate into the substratum. (× 1000, scale C)
3. A perithecium with part of the substratum dissected away. The outer mycelial threads have also been removed. (× 25, scale D)
4. A typical ascospore with hyaline, sticky terminal appendages. (× 425, scale B)
5. A very immature ascus. (× 425, scale B)

Figs. 6–7. *Halophiobolus longirostris* Linder.

6. A perithecium as seen in sectional view to show the relatively thick subhyaline wall and the long ostiolar neck from which the mycelium has here and there grown out to fill adjacent cells of the substratum. (× 25, scale D)
7. A section of the perithecial wall showing the thin inner layer of slender, elongate protoplasm-filled cells, the thick middle layer composed of angular, enlarged, subhyaline cells, and the thin outer layer of darkened and closely intertwined cells. (× 1000, scale C)

Figs. 8–11. *Halophiobolus salinus* Linder.

8. Two perithecia to illustrate the variation in size and shape. The upper portions are dark fuscous or nearly black and shading off to buff-colored below. (× 25, scale D)
9. Three characteristic ascospores. (× 425, scale B)
10. Detail of the hyaline terminal appendages of which that on the left has begun to deliquesce. (× 1000, scale C)
11. Chain of conidia formed in culture on agar. (× 425, scale B)

Figs. 12–14. *Halophiobolus cylindricus* Linder.

12. A perithecium showing the subcylindrical shape, the swollen base of the long protruding ostiolar neck. (× 25, scale D)
13. Two ascospores with characteristic elongate, tapering, hyaline appendages. (× 425, scale B)
14. A terminal appendage more highly magnified. (× 1000, scale C)

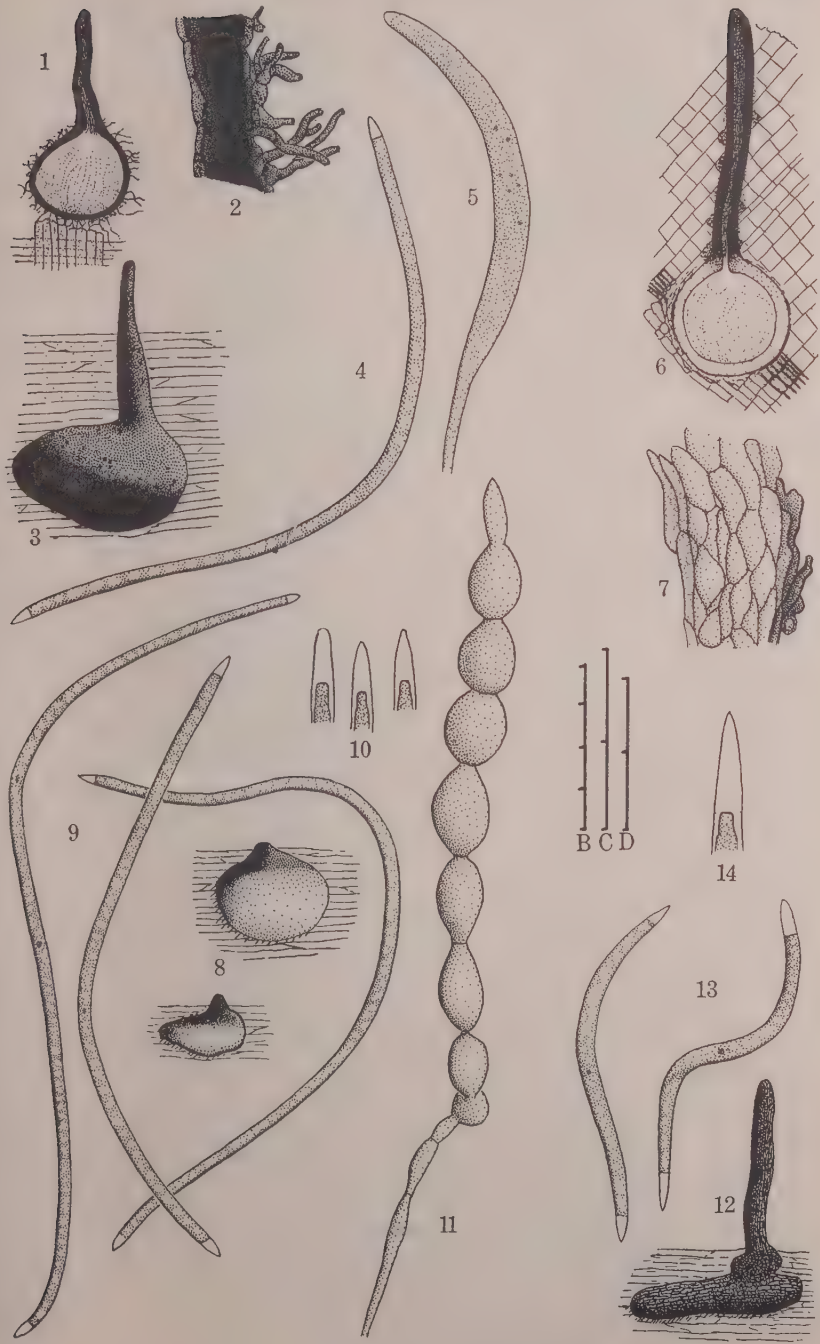


PLATE VI

II. BIOLOGICAL ASPECTS

E. S. BARGHOORN

Microbiological studies in recent years have clearly demonstrated the significance of bacteria as active agents in many of the decomposition processes which occur in submerged plant remains (Waksman, 1936; Waksman and Stevens 1929, Waksman *et al.* 1933, Allgeier *et al.* 1932). The possible rôle of fungi in such processes in the sea has received little attention, however, except in the case of certain fungal parasites (Sparrow 1936, Renn 1936). In the degradation of organic matter in the sea the actual existence of saprophytic truly marine fungi has been seriously questioned by certain authors (Waksman 1934). Indeed, it is commonly assumed that the lower availability of oxygen in conjunction with a less vigorous fungal flora render unlikely any considerable fungal action on organic matter at appreciable depths under water. The depletion of available oxygen by saprophytic bacteria and other microörganisms working on the surfaces of decaying organic detritus would *a priori* support the view that fungal action is greatly reduced if not inhibited under such conditions.

A survey of the literature, however, reveals a paucity of information concerning the microbiological, microchemical and histological changes which occur in submerged plant materials, particularly wood, which have been immersed in salt, brackish or fresh water for considerable time. Not only are the histological changes resulting from the decomposition processes incompletely known, but the chemical composition of specific plant constituents in bottom deposits is not well understood.

Recent microchemical and anatomical study of certain submerged woods of recent geological age indicate that the relative significance of purely chemical and of microbiological factors in decomposition is difficult to determine (Bailey and Barghoorn 1942). In the latter investigation wood buried deeply in estuarine silt for presumedly not less than 2000 years was found to have undergone very extensive chemical degradation involving the loss of 95 per cent of its original cellulosic constituent and the major portion of its pentosan complexes but with little or no change in lignin content (Jahn and Harlow 1942). Histological and microchemical examination failed to reveal the presence of microörganisms inducing decay, although the fungal hyphae of terrestrial wood-rotting forms infecting the wood before it was submerged were well preserved and easily demonstrated.

Non-mineralized fossil woods of far greater antiquity such as certain deeply buried coniferous remains from the auriferous gravels of California, on the other hand, show a remarkable preservation of both physical and chemical structure (Mitchell & Ritter 1934, Barghoorn and Bailey 1938). In material such as this, although of Miocene geological age, it is evident that neither microbiological nor extensive chemical action has occurred.

Many deposits of greatly altered plant materials, such as lignite, brown coal and *certain* peats are highly modified both chemically and physically and yet exhibit little or no indication in most cases as to the influence of microörganisms inducing specific modifications, although the initial changes are usually interpreted as biological in origin. (Waksman 1936, Thaysen 1930).

A large proportion of plant materials which are preserved either as isolated fossils, or in extensive deposits of varying thickness, has been exposed at one stage or another to the conditions of submergence in salt, brackish, or fresh water. It is desirable, therefore, to investigate the initial changes which occur in plant materials upon continued exposure to these conditions in order to establish the first steps in the long sequence of events which lead to the ultimate preservation, degradation or complete decomposition.

A convenient and significant starting place for such studies has been found in the changes which occur in plant materials exposed to the sea and variously modified conditions of the marine environment.

It is well known, although perhaps not as widely recognized as might be expected, that plant materials of economic importance such as wood and cordage undergo a steady deterioration in sea water which cannot be assigned to the activities of marine borers, or other similar organisms. In the case of wooden pilings the obvious depredations of *Teredo* and *Limnoria* are well known. However, a conspicuous softening occurs in the outer parts of piling and submerged wood which clearly does not result from the activity of these wood destroying marine animals. Similarly, cordage, particularly of untreated fiber, quite rapidly deteriorates upon continuous exposure to sea water and less rapidly with intermittent submergence. The often quoted "preservative" effect of sea water is certainly not to be noted in materials constantly exposed to marine conditions, although the salt treatment of timbers, effected by drying after prolonged immersion in sea water, does serve to retard the activities of terrestrial wood rotting organisms as well as the development of the airborne spores of fungi which normally attack damp, readily available organic materials such as wood and its various constituents.

In an early phase of these investigations on the decomposition of wood submerged in sea water it became evident that fungi are extremely common in such materials under *aerobic* conditions, though *totally absent under anaerobic* conditions. Accordingly contemplated bacteriological studies in the decay of submerged wood were set aside and efforts made to isolate and culture the fungi, which comprise a far more conspicuous and vigorous element of the microflora involved in the decomposition.

The occurrence of abundant perithecia and ascospores of many species of the fungi facilitated the isolation of pure cultures. Other forms have been brought into culture from their conidial stages. Certain species of undoubted marine occurrence have been found only in their vegetative

phase in decaying cordage and wood. Experimental studies on the biology of fourteen species of this interesting group of fungi have been made, other forms having been isolated more recently. The present paper deals in particular with the physiological behavior of seven representative species, all of which have been isolated by spore culture from their ascospore stages.

MATERIALS AND METHODS

The fungi with which this study is concerned were obtained from specimens of wood or cordage exposed for varying lengths of time to the full salinity of sea water or to the brackish waters of estuaries. In general, two types of materials were used, viz., specimens of wood or cordage of known conditions and duration of submergence, and specimens of wood and cordage of undetermined length of exposure. In all cases the fungi were isolated from a natural substratum which was either continuously submerged in water or covered for the greater part of the interval elapsing between successive high tides. A summary of the specimen collection data is included in the introduction.

The "test" boards and blocks referred to in this paper were supplied through the courtesy of the William Clapp Laboratories in Duxbury, Mass. These blocks, chiefly of fresh-sawed hard pine, had been exposed for six to twelve months at a depth of two to eight feet below low water and had not been exposed to the air from the time of their submergence until the date of removal. Abundant perithecia on the surface of or embedded in many of the blocks provided an excellent source of material for spore isolations. The majority of the blocks were examined and used as sources of inoculum within three or four days after their removal from the water. This brief period of time precludes the possibility of perithecium production by any contaminating terrestrial fungi. Further proof that perithecium production is commonly vigorous under sea water was obtained by sectioning specimens of wood freshly collected from Cape Cod Bay and Provincetown Harbor. Sections of such material, bearing perithecia with viable spores, also show the presence of a very extensive and vigorous mycelium in the wood. Comparable material has recently been obtained from Chesapeake Bay, Maryland, and Biscayne Bay, Florida.

In addition to wood, specimens of submerged rope and cordage were examined for attack by fungi. All rope samples which have been studied whether of treated or untreated material show varying degrees of infection and deterioration by fungi. In cases in which perithecia occurred on or embedded in the rope the species have been found identical with those obtained from wood blocks. Although studies are now in progress on the mode and rate of attack of the marine fungi on both wood and cordage it is desirable to point out here that rope, because of its fibrous texture, appears to be more readily attacked than wood by the cellulose destroying members of the group.

In addition to the collection data tabulated in the introduction the following locations along the Atlantic Coast have yielded specimens of wood (or cordage) bearing perithecial stages of marine fungi:

Newfoundland
- Corner Brook

Maine
- Eastport
- Machias
- Portland
- Rockland
- Wiscasset

Massachusetts
- Beverley
- Boston
- Charlestown
- Edgartown
- Gloucester
- Marshfield
- Neponset
- Quincy
- Vineyard Haven
- Weymouth

Connecticut
- South Groton

New York
- City Island
- Rosebank, L. I.

Maryland
- Gibson Island, Chesapeake Bay

Florida
- Biscayne Bay

In isolating certain of the fungi from the natural substratum great difficulties were encountered in freeing the germinating spores from bacteria. The poured plate method using nutrient agar made up in sea water usually proved useless owing to the very rapid spread of motile marine bacteria which frequently destroyed the spores even before their germination occurred. Modifications of the sprayed-spore technique (Wehmeyer 1923) were likewise of little value. The acidification of the spore suspension to retard bacterial activity completely inhibited germination of the fungal spores. The best results were obtained with stab cultures made by detaching a small mass of spores from an exuding or crushed perithecium and thrusting it with a streaking motion deep into agar. The spores, germinating beneath the surface of the agar, rapidly developed a bacteria-free mycelium. In certain cases, however, the rapid spread of bacteria on the surface of the agar made it necessary to invert the stab-culture plates, free the agar from the dish and cut blocks from the lower surface in order ultimately to free the fungus from bacteria. The excessive motility of certain of the bacteria, in conjunction with a definite agar-liquefying activity, permitted their development along agar-glass interfaces, although they were unable to penetrate deeply into free agar. In making the stab cultures, therefore, the needle was not allowed to penetrate completely through the agar layer. This precaution prevented the spread of bacteria on the lower surface of the culture. The medium most useful for spore germination with a minimum of bacterial growth was a three per cent crude unwashed agar made up in sea water.

In determining the reaction of the fungi to the substratum, to temperature, and to hydrogen-ion concentration various agars were used. All of the media, with the exception of the fresh water and concentrated sea water, were solidified with three per cent Bacto agar made up in filtered sea water with added nutrient.

Stock cultures were maintained on a four per cent agar containing 0.5 per cent malt extract. Other agars were made up as follows:

Cellulose agar. One per cent regenerated cotton cellulose prepared by the method of Northrup (1919), pH 7.4 [1].

Maltose, Xylose and Galactose agars. Sugar concentration two per cent, pH 7.4.

Starch agar. Two per cent purified corn starch, pH 7.5.

Asparagine agar. Four-tenths per cent asparagine Merck, pH 7.2.

Pectin agar. Five-tenths per cent lemon pectin purified by the method of Baxter (1925) pH 6.5. The pH of the pectin agar was adjusted to 7.2 before use by the addition of dilute sodium hydroxide. This medium doubtless contains many degradation products of pectin hydrolysis.

Wood flour agar. 0.75 per cent finely powdered white pine filings. The wood dust was extracted with boiling chloroform, and repeated treatments with benzol and absolute alcohol to remove, insofar as possible, the resins and terpenes. The treated wood was washed repeatedly with boiling distilled water and dried on a Buchner funnel. pH 7.4.

Fresh water agar. Glass distilled water four parts, tap water one part. pH 7.2. Tap water contained traces of organic matter in addition to traces of inorganic salts.

Sea water agar. Filtered sea water with no added nutrient, pH 7.4.

Concentrated sea water agar. Prepared from sea water evaporated to exactly one-third its original volume, with no added nutrient. A portion of the calcium precipitated out during evaporation. pH 8.2.

The agar used for the study of the influence of temperature was made with four-tenths per cent malt extract and no additional nutrient. The experiments on the influence of hydrogen-ion concentration were run with five per cent malt extract agar; the medium was acidified by the addition of hydrochloric acid and made alkaline by addition of sodium hydroxide.

In studying the rate of radial growth of the fungi in culture a more or less standardized procedure was followed. Pure cultures of the various species were maintained by repeated transfers on a stock culture medium in Petri dishes. Small blocks of this medium, one to two millimeters square were used as inoculum in the various growth studies. The blocks were cut from the outer third of the spreading mycelium. Rate of radial growth was determined by measuring the spread of the mycelium on Petri dish cultures containing the different media. After inoculating the plates the colonies were allowed to grow for three to six days and then measured. Measurements were made radially in three directions from the edges of the inoculum to the outer extreme of the mycelial mat. The plates were then incubated for a varying length of time, in most cases six to ten days, and measured again. The rate of radial growth was taken as the increase in radius of the colony in millimeters per day between the first and second measurements. The value for any one measurement was obtained by averaging the three readings.

[1] pH values are for media after sterilization.

In eliminating from measurement the growth for the first three to six days, the influence of nutrient carried over in the inoculum was greatly reduced.

Although radial increase of a colony is a rather arbitrary index of the amount of growth of a mycelium it is by and large a more practical means of measurement than determinations of dry weight increase. As far as was practicable in this study the radial increase of the colony was roughly correlated with the apparent visible density of the fungal mat. In all but a few cases extensive radial spread was quite closely associated with abundant branching and production of hyphae. The cases in which this correlation did not obtain, were those of "starvation media" such as the fresh water and pure sea water cultures. Certain species on these two media produced extremely sparse but far-ranging mycelia. These facts must be taken into account in considering the rate of growth on certain of the media deficient in available nutrient.

In preliminary experiments to determine the availability of different carbohydrates it was found that the depth of medium in the culture dish exerted considerable influence on the rate of spread of the mycelium. Certain species spread more rapidly on deep cultures while others spread more rapidly on shallow cultures. In order to counteract this effect which is particularly significant in the study of the influence of temperature and hydrogen-ion concentration, the plates were poured to as uniform depth as possible and then sorted before inoculation so that a given species was grown on media of the same depth.

The growth studies in this investigation were made with fourteen selected species of fungi obtained either by spore isolation or direct inoculation from infected material. Inasmuch as the latter source of cultures always presents the uncertainty of possible contaminating organisms not originally present in the material, only species obtained from spore isolations are considered in detail. Of these, seven species were selected as representative of the marine fungi as a group. The seven species cover fairly well the morphological range of the forms known at present and probably represent fairly well the physiological diversity of this interesting group of fungi.

RELATION TO SALINITY

As indicated by the collection data summarized in the introduction, the marine fungi occur naturally in both brackish water and sea water of normal salinity. In view of their undoubted derivation from terrestrial forms it seemed interesting to determine their reaction in culture to extremes of salinity as some measure of their adjustment to the marine environment. For this purpose five species were chosen and grown on three different media: fresh water, normal filtered sea water and sea water evaporated to one-third its original volume. The three series of experiments were run in duplicate, simultaneously and at the same temperature.

TABLE 1. EFFECT OF SALINITY ON RATE OF RADIAL GROWTH

	Radial Growth in Millimeters Per Day		
	Fresh water pH 7.2	Sea water pH 7.4	Concentrated Sea water pH 8.2
Amphisphaeria maritima	.55	.30	.12
Helicoma salinum	.68	1.14	.31
Peritrichospora integra	.79	.96	.38
Ceriosporopsis halima	1.33	1.17	.54
Halophiobolus opacus	.52	3.10	.07
Halophiobolus salinus	2.74	3.16	.07

In Table 1 it will be noted that two species, *Amphisphaeria maritima* and *Ceriosporopsis halima* develop more rapidly in fresh water than in sea water, while the remainder grow radially at a more rapid rate in normal sea water. In concentrated sea water, the growth rate for all is considerably decreased although *Ceriosporopsis halima* and *Peritrichospora integra* grow at nearly one-half the rate determined in fresh water. An important factor in the experiment which is not expressed in the table is the relative denseness of the mycelia. In all cases the hyphal production per colony area was conspicuously greater in normal sea water than in either fresh water or concentrated sea water. In fresh water agar the hyphal mats were more hyaline and the hyphae less branched, particularly in the outer third of the colony. In concentrated sea water the hyphae branched abnormally, the secondary hyphae being crooked and much shortened. In this latter medium it might be presumed that the higher pH value would adversely affect growth. However, as will be shown later, a pH of above 8.0 is more favorable for growth in culture than a pH below 8.0 in the case of at least three species.

Although *Amphisphaeria maritima* and *Ceriosporopsis halima* in the above experiments showed a more rapid radial growth in fresh water than sea water, neither of these species shows preference for such conditions in nature as far as collection data and field study indicate. Indeed, their occurrence in fresh water is to be doubted, although further collections may demonstrate their presence in the non-saline portions of estuarine rivers. Of the five species studied in respect to salinity reactions all but *Halophiobolus opacus* and *Peritrichospora integra* have been collected from brackish waters as well as the open sea.

Two species of the marine fungi, *Halophiobolus opacus* and *Remispora maritima* were collected in conditions in which a fairly high salt content presumably occurred in the natural substratum. Both of these forms were found, in the perfect stage, on wooden pilings in such a situation as to be exposed to the drying action of wind and sun for many hours at low tide, although completely submerged at high tide. *Remispora maritima* in particular was collected on wood exposed to the air for six to seven hours between tides. Such conditions would suggest a high tolerance to salinity as well as to sudden changes in salinity such as would occur with recurring incoming tides.

In general, considering both ecological factors and the results from experimental cultures, there is considerable evidence that the marine fungi possess an adaptation to or tolerance of the saline conditions in the environment of the sea.

RELATION TO SUBSTRATUM

In view of the natural occurrence of the fungi on wood, rope and other plant materials of similar chemical composition, a series of experiments were run to determine the relative availability of certain carbohydrates. For this purpose the sugars maltose, xylose and galactose and the carbohydrates cellulose, starch and pectin were employed. An artificial medium containing wood in a finely divided state was also tried in an effort to establish in a rough quantitative manner the relative wood destroying powers of the various species. A medium containing nitrogen in the form of asparagine was used to determine the availability of organic nitrogen. The latter series of experiments is rather interesting inasmuch as the fungi under natural conditions very commonly become established on material covered by surface growths of various benthonic organisms, presenting upon decomposition a readily available supply of organic nitrogen.

In determining the reaction of the various forms to particular artificial media, the experiments were run in such a way as to provide uniform conditions for the medium being tested. This procedure was used in preference to conducting a group of experiments synchronously with a particular species on the whole series of media. The former method probably provides more reliable data on the relative availability of a given substratum to different species, although uniformity of conditions for a given species are sacrificed to a certain extent.

Two isolates of *Ceriosporopsis halima* were used in all the experiments on reaction to substratum, to pH, and to temperature. One of these, *Helicoma salinum,* was isolated as the imperfect stage while the perfect stage, *Ceriosporopsis halima,* was later obtained from ascospore isolations. These two strains of the same organism show a decided similarity in their reactions to different substrata, hydrogen-ion concentration and temperature differences. *Helicoma salinum* was isolated from a wood block bearing an abundance of its gray-black helical spores. In culture, the mycelium produced similar spores in large numbers. Subsequently, on another wood specimen, perithecia of *Ceriosporopsis halima* were found in large numbers. Spore cultures from the latter yielded mycelia and helical spores identical with those of the *Helicoma.* In view of this, the two isolates were carried along in all cultural experiments. The results furnish interesting evidence from a physiological point of view for their taxonomic treatment as the perfect and imperfect stages of the same species.

RATE OF RADIAL GROWTH ON ARTIFICIAL MEDIA

Following the general procedures employed by Brown (1923), Linder (1929), Howell (1940) and other workers who have contributed data on the rate of growth of fungi in culture, the rate of spread of the mycelium was used in this study as an index of the availability of the substratum for growth. As has been pointed out previously, this procedure is open to some error, but, by and large, it is the most practicable means of determining the vigor of a fungal colony in response to available food materials and particularly so in the case of synthetic media containing insoluble materials such as cellulose, wood or lignin. A summary of the statistical data derived from the growth of the fungi on various nutrient media is shown in Table 2.

TABLE 2. RATE OF RADIAL GROWTH IN MM PER DAY ON NUTRIENT MEDIA

	Cellulose	Maltose	Galactose	Xylose	Starch	Pectin	Asparagine	Wood Flour
Amphisphaeria maritima	.32	.40	.17	.35	.32	.32	.08	.31
Helicoma salinum	1.56	1.55	.91	1.17	1.86	1.50	.83	1.44
Peritrichospora integra	1.17	.05	.52	1.04	.97	1.13	1.01	1.13
Ceriosporopsis halima	1.09	1.10	.52	1.09	1.20	1.33	.47	.96
Halophiobolus opacus	2.61	.12	.14	.54	2.50	1.82	2.80	.84
Halophiobolus salinus	4.47	1.90	2.07	2.76	4.07	3.43	2.97	3.34
Halophiobolus cylindricus	1.22	.87	.76	.76	1.10	.90	.87	1.08
Phialophorophoma litoralis	.62	1.09	.77	.55	.91	1.08	.95	.39

1. Cellulose

A carbohydrate invariably present in the natural substrata from which these fungi have been isolated is cellulose. As might be expected, therefore, both growth and spore production are favorable on cellulose media. The availability of cellulose in supporting the radial growth of seven species in culture is shown in Fig. 1. It will be noted that *Halophiobolus salinus*, of the species represented, not only shows the greatest absolute rate of growth but also the greatest relative radial growth on cellulose. Similarly *Halophiobolus cylindricus* and *Peritrichospora integra* make their most rapid development on cellulose of the various carbohydrates supplied as substrata. For the remaining species cellulose provides one of the more favorable carbohydrate media, and only in the case of *Amphisphaeria maritima* and possibly *Ceriosporopsis halima* is growth slower than on a medium containing maltose as the sole carbon source.

The ability of the fungi to produce cleared spots on cellulose agar is not closely related to their rate of radial growth on cellulose as compared to other substrata. Thus, certain cultures of *Peritrichospora integra* produced definite, cleared "halos" on cotton cellulose plates within a period of 72 to 96 hours whereas cultures of *Halophiobolus salinus* on

the same medium produced poorly differentiated clear zones, despite the fact that cellulose supported a more rapid growth than any other carbohydrate supplied in the medium. Similarly, the cellulose digesting power of *Halophiobolus cylindricus*, indicated by rate of growth on this substratum, was not demonstrated by the formation of a conspicuous clear zone in the plates. On the contrary, cultures of *Amphisphaeria maritima* on cellulose plates, although of slow growth, produced cleared areas adjacent to the mycelial mat despite the fact that the rate of growth on this substratum was less than that on maltose, xylose, pectin and even wood flour. Hence, it may be reasoned from the evidence derived from such culture experiments that the intensity of cellulase activity of the various forms in culture is not clearly indicated by their relative rate of growth on cellulose agar media. More critical measure of the cellulose digesting powers of selected members of the marine fungi is at present being studied through their enzyme production and ability to attack wood under experimental conditions.

In this connection it is of interest to note that the ability of an organism to attack cellulose is not always clearly demonstrable by its development on synthetic media containing regenerated cellulose. This behavior is probably due in part to the fact that synthetic cellulose media contain modified forms of cellulose, such as oxycellulose and other degradation products as well as to the fact that cellulose destroying organisms in nature develop on substrata containing a wide variety of carbohydrate compounds, which, singly or in combination, are favorable to a more "normal" and vigorous development. It has been observed that in the case of many Basidiomycetes, growth is unsatisfactory on plate cultures, whereas extensive cellulose decomposition is actually effected in the medium, as may be shown by analysis (Norman and Fuller, 1942).

The influence of cellulose and other substrata on the color of the colonies and spore production is shown in Table 3. It will be noted that cellulose produces, in general, an effect similar to that of xylose and of wood flour, particularly the latter. There is, however, no specific influence or particular effect exerted by the presence of cellulose on the color of the colonies; nor is there anything to suggest that the availability of cellulose, or any other carbohydrate supplied is indicated by the intensity of pigment formation in the mycelial mat or in the adjacent medium. For example, *Peritrichospora integra*, a form possessing marked cellulose digesting power, produces no colored products on either cellulose or wood flour agars, although the mycelium production and rate of growth are greatest on these substrata. *Amphisphaeria maritima* is interesting also in this connection, since it produces a characteristic brown tawny color on cellulose, xylose and wood flour and remains white on maltose agar, a medium which supports the most rapid radial growth as well as very abundant mycelial development.

Data regarding the effect of cellulose and other substrata on spore

production are very unsatisfactory owing to the failure of most forms to produce spores in Petri dish cultures within a reasonable period of time. However, *Ceriosporopsis halima,* which produces conidiospores freely on a wide variety of substrata, attained its greatest spore production on cellulose and wood flour agars. Similarly *Halophiobolus opacus,* although normally producing few spores, sporulated quite vigorously on cellulose and wood flour with virtually no spore production on other substrata. In *Ceriosporopsis halima* and *Halophiobolus opacus* it is evident that spore production is not influenced by deficiency of available carbohydrate since both of these forms grow with considerable speed and vigor on cellulose and wood flour (Table 2). Hence, although the evidence is somewhat meagre there is no indication that a deficiency of available carbohydrate stimulates spore production. In this regard it is interesting to note that on galactose and asparagine, *Ceriosporopsis halima* made a feeble growth and produced no spores.

2. Maltose

Although the disaccharide maltose furnished a very favorable substratum for certain species of the fungi, cultures of *Halophiobolus opacus, Peritrichospora integra* and *Halophiobolus salinus* made a conspicuously poor growth on this carbohydrate. These effects were so pronounced in the case of *P. integra* and *H. opacus* that several series of cultures were run in order to reduce the possibility of experimental error. The additional cultures, however, yielded consistent results. If reference is made to the cellulose digesting power of these forms illustrated in Fig. 1, it will be noted that the three species show definite negative correlation in respect to the availability of cellulose as contrasted with maltose. Whether or not this has any general significance is difficult to determine from the small number of cases studied; certainly it is not true of the forms *Halophiobolus cylindricus* and *Ceriosporopsis halima* for which both maltose and cellulose are readily available. However, it is interesting to note that in the helicosporous fungi imperfecti studied by Linder (1929), two species, *Helicomyces scandens* and *Helicondendron tubulosum,* made their most rapid growth on cellulose and their poorest growth on maltose, a very similar response to that exhibited by the marine fungi *Peritrichospora integra* and *Halophiobolus opacus.*

Maltose provided the most favorable substratum for rapid radial growth in cultures of *Amphisphaeria maritima* and *Phialophorophoma litoralis,* for both of which forms cellulose is also an available nutrient. *A. maritima,* however, despite the rapid radial growth on maltose did not produce a dense mycelium such as formed on wood flour, xylose or cellulose agars. Moreover, the pronounced brown color of the colonies on the three latter media is not developed on maltose. *Phialophorophoma litoralis,* on the other hand, not only made its most rapid radial growth on maltose, but also developed an extremely thick felty mycelial mat.

TABLE 8. INFLUENCE OF SUBSTRATUM ON COLONY COLOR AND SPORE PRODUCTION. COLONIES 18–21 DAYS OLD

FIGURE DENOTES APPROXIMATE PERCENT OF SPORE PRODUCTION

	Cellulose	Maltose	Galactose	Xylose	Starch	Pectin	Asparagine	Wood Flour
Amphisphaeria maritima	Brown 0	White 0	White 0	Dark brown 0	White 0	Buff 0	White 0	Dark brown 0
Peritrichospora integra	White 0	White 0	Brown gray 0	Light gray 0	Light gray 0	Gray green 0	Cottony white 0	White 0
Ceriosporopsis halima	Gray 100	Very light gray 10	White or hyaline 5	Gray 30	Iron gray 50	Light gray 75	White or hyaline 5	Gray 100
Halophiobolus opacus	Light olive green 10	White 0	White 0	White 0	Yellow brown 0	Brown gray 0	White or hyaline 0	White 10
Halophiobolus salinus	Yellow brown 0	Faint yellow brown 0	Green gray 0	Yellow brown 0	Mouse gray 0	Dark brown gray 0	White 0	Yellow brown 0
Halophiobolus cylindricus	Cottony white 0	Cottony white 0	Cottony white 0	Cottony white 0	Cottony white 0	Cottony white 0	White 0	Cottony white 0
Phialophorophoma litoralis	Mouse gray 0	Green gray 0	Green gray 0	Rust red brown 0	Brown gray 0	Gray 0	Light gray 0	Green gray 0

The growth of the two isolates *Ceriosporopsis halima* and *Helicoma salinum* on maltose, as compared to cellulose, is interesting in view of the nearly identical relative growth despite the difference in the absolute rates of growth of the two strains. In Fig. 1, it will be noted that the *Helicoma* isolate shows an equal growth rate on the two media. This is also the case with the ascospore isolation of *C. halima.* However, the actual rate of growth of the strain isolated from the conidial stage is approximately 30 per cent greater than that from the ascospore stage. This similarity in relative growth rates for the two strains of *C. halima* on different substrata is not confined to maltose and cellulose as can be noted in the graphs in Fig. 1. The difference in absolute growth rate of the two strains is likewise nearly of the same order of magnitude on the various other media.

Insofar as the color of colonies and the production of spores is concerned maltose shows no particular influence. In general, pigment formation was conspicuously less pronounced than on cellulose agars and in the case of *Amphisphaeria maritima, Peritrichospora integra, Halophiobolus opacus* and *Halophiobolus cylindricus* the mycelia were totally devoid of color, consisting of hyaline or cottony white mats (Table 3).

3. Galactose

Galactose as a source of carbohydrate for fungi has been variously interpreted in several studies on the development and rate of growth of fungi in culture. Horr (1936), by dry weight determinations, found that galactose as the sole carbohydrate source provided a poor substratum for two species of *Penicillium* and *Aspergillus.* Recently Edgecombe (1938) demonstrated that galactose is readily available to certain forms, though not to others, as evidenced by contrasting rates of radial growth on agar media.

The availability of galactose to the group of fungi under discussion here is significant not only in the light of previous studies but also in view of their ability to hydrolyze and penetrate the pectic materials of the isotropic intercellular substance of woody tissues. Although the ability to break down pectic compounds in the intercellular substance is not a sure indication that the galactose constituent of the pectic material can be utilized it seemed desirable to test this possibility by comparing growth on galactose with growth on pectin media.

Insofar as such a correlation between pectin utilization and growth on galactose is concerned, the results are indifferent, if not negative, as can be noted in Fig. 1. Indeed, *Ceriosporopsis halima* which made its most rapid growth on pectin agar developed very poorly on galactose. However, it is interesting to note that galactose provided a better source of nutrient than maltose for the more active cellulose digesting forms, *Peritrichospora integra, Halophiobolus opacus,* and *Halophiobolus salinus;* while in only two species, *Amphisphaeria maritima* and *Ceriosporopsis halima* was galactose inferior to all other carbohydrates as a food source.

The nature of the mycelial development on galactose was quite abnormal in certain forms, which developed curiously twisted and "gnarled" hyphae on galactose agar, although exhibiting a moderate radial growth. On galactose the average diameter of the hyphae in *Peritrichospora integra*, *Halophiobolus opacus*, and *Halophiobolus salinus* was less than on any other carbohydrate medium.

Pigment formation on galactose agar plates after three weeks incubation was less than on any other carbohydrate substratum, except in cultures of *Peritrichospora integra*. The latter form developed a peculiar brown gray color on galactose which was distinctly in contrast to the pigmentation produced on any other medium.

Spore production on galactose occurred only in cultures of *Ceriosporopsis halima*. The helical spores (*Helicoma salinum*) were produced very sparsely and examination showed an almost complete absence of the usual dark pigmentation of the spore wall. The spores, moreover, were curiously abnormal in shape, lacking the usually complete curvature. In this respect the conidiospores closely resembled those produced on media deficient in nutrient, such as plain sea water agar (Table 1).

In general the experimental evidence indicates that galactose is a relatively poor nutrient for the growth of these fungi but as determined by rate of radial growth, it is available in some measure to all of them.

4. Xylose

The presence of xylan in the secondary wall of woody cells in conjunction with the rather ready microbiological decomposition of the pentosan and hexosan hemicelluloses suggest that xylose might provide an available substratum for wood inhabiting fungi. In this study d-xylose proved a rather indifferent source of carbohydrate for the various marine forms. In no case did xylose support more vigorous growth than certain other carbohydrates, while in cultures of *Halophiobolus cylindricus* and *Phialophorophoma litoralis* development was actually slower than on any other simple substratum. *Amphisphaeria maritima* is the only species of the entire group which made a conspicuously rapid and vigorous growth on xylose, the mycelium of this form not only spreading extensively but also branching profusely in a dense hyphal mat or cushion.

The influence of xylose on pigment formation is interesting in the case of *Phialophorophoma litoralis* which developed an intense rust red-brown color on this medium although showing no similar pigmentation on other substrata including even such complete nutrient as potato agar. *Amphisphaeria maritima* produced a dark brown pigmentation both in the mycelium and in the medium on xylose substratum (Table 3).

Conidiospore production by *Ceriosporopsis halima* was fairly heavy on xylose agar although less than a third of that on cellulose or wood flour (Table 3).

5. Starch

Starch is among the carbohydrates not infrequently present in the carbohydrates comprising the natural substratum of these marine fungi and it is therefore not surprising to find that it supports a vigorous vegetative development.[2]

As shown in Fig. 1 starch was readily utilized by all of the species studied and particularly by *Halophiobolus opacus, Halophiobolus salinus* and *Ceriosporopsis halima.* In the case of the *Helicoma salina* isolate, the most rapid radial growth on the various media used in this study occurred on starch agar. As indicated by radial growth and hypha production, starch proved to be an excellent carbohydrate source for the development of all three species of *Halophiobolus.*

In none of the cultures was starch a definitely inferior food source for these fungi, although *Peritrichospora* produced a rather sparse mycelium on this medium, despite relatively rapid radial growth.

For determining the diastatic activity of the marine fungi on plate cultures of starch media a simple iodine color test was used. Week-old cultures were covered with dilute IKI solution until the characteristic blue color reaction of starch developed in the agar. Differences in intensity of staining in and around the portions of the medium penetrated by the mycelium, indicated clearly the extent and the degree of degradation of the starch. In certain cases starch digestion was sufficiently advanced near the point of inoculation to result in a clear or colorless zone. All species of the marine fungi investigated by this technique showed a well developed diastatic activity.

Spore production by *Ceriosporopsis halima* was considerably higher on starch than on maltose, galactose or xylose, although only about one half that on cellulose. The spores showed their normal black pigmentation.

6. Pectin

Thin sections of infected wood in either the radial or tangential longitudinal plane show that all of the fungi described in this study are capable of penetrating the cell walls of woody tissues in passing from lumen to lumen of adjacent cells. In this process the hyphae penetrate the pectic compounds of the isotropic intercellular substance as well as the highly lignified primary walls and thick secondary walls. In passing transversely through the wall, as will be described in more detail later, the hyphae narrow down to a tenuous thread and grow directly through the various wall layers, widening out again immediately upon entering the lumen of the adjoining cell.

A priori it would appear that pectin hydrolyzing enzymes would necessarily be produced in order that the hyphae might penetrate the intercellular pectic substances. Such action, moreover, presumably indicates

[2] The starch used in the growth experiments was a purified corn starch carefully freed of proteinaceous substances and hemicelluloses.

that the hydrolytic products may be utilized by the fungus. The experiments using pectin as a substratum demonstrate that this is the case.

In Fig. 1 it will be noted that all seven species including both strains of *Ceriosporopsis halima* make a favorable growth on pectin agar. In no case is pectin an unavailable or even inferior source of nutrient, while in cultures of *Peritrichospora integra* and one strain of *Ceriosporopsis halima* it supports a very rapid radial growth.

It is interesting to note that the response to both cellulose and pectin exhibited by this group of marine fungi is quite similar to that found in eight species of the helicosporous Fungi Imperfecti (Linder 1929). Certain members of the two groups are of course very closely related but it is a striking fact that the nutritional behavior should be so similar in view of other considerable physiological divergences between the marine and terrestrial members of the two groups.

A factor which should be noted in experiments using pectin agar is the ready hydrolytic decomposition of pectin during the process of steam sterilization. Even in alkaline sea water pectin agars registered a pH of 6.5 after autoclaving for fifteen minutes. This lowered pH was difficult to readjust inasmuch as the addition of dilute sodium hydroxide would not produce a permanent change in pH until after the solution had cooled to below 50° C. Above this temperature the change in pH produced by sodium hydroxide was transitory, the reaction rapidly tending toward acid again. It is clear therefore that certain decomposition products of pectic origin are present in the medium even after the above precautions have been taken. These facts, however, do not invalidate conclusions drawn as to the availability of pectic substance to the fungi, particularly when the experimental data is correlated with the action of the fungi on a natural substratum containing pectic compounds.

The effect of pectin on colony color and spore production is most pronounced in cultures of *Peritrichospora integra* and *Ceriosporopsis halima*. *Peritrichospora integra* produced a dark gray-green pigmentation both in the hyphae (submerged hyphae chiefly) and in the medium. The intensity of pigmentation in the pectin cultures of this form was greater than in any other medium with the exception of the complex potato-dextrose agar. *Ceriosporopsis halima* exhibited no unusual color reactions on pectin although the amount of pigmentation was great. Correspondingly, spore production was vigorous, being about 75 per cent of that on cellulose agar.

7. Asparagine

The availability of simple organic compounds of nitrogen in a synthetic medium was determined by using substratum containing small quantities of asparagine. This highly mobile nitrogenous compound is present in nearly all living plant tissues though probably virtually absent in the normal environment of these saprophytic fungi.

The availability of asparagine is perhaps not satisfactorily determined by this series of experiments owing to the great deficiency or complete absence of carbohydrate in the substratum. However, a selective effect is manifested by the very diverse responses made by various species as shown in Fig. 1.

The extraordinary radial growth of *Halophiobolus opacus* on asparagine agar must be interpreted in correlation with the characteristics of the mycelium on this medium. Although radial growth was extensive the colonies were very sparsely branched, produced no aerial hyphae and appeared quite hyaline in transmitted light. On both cellulose and starch agar, the radial growth of this species was somewhat less than on asparagine, but the colonies developed a more luxuriant and vigorous mycelial mat.

Asparagine afforded the poorest substratum for growth in cultures of *Ceriosporopsis halima* and *Amphisphaeria maritima.* Other species appear to utilize asparagine to a somewhat greater degree although in none of the colonies was the hyphal mat vigorously developed. In fact, the data for growth on asparagine as indicated by radial extent of the colonies is somewhat misleading owing to the consistently sparse development of the hyphae in this medium. Another consistent reaction of the various forms to this substratum was the deficient development of aerial hyphae. Only in the case of *Amphisphaeria maritima* and *Halophiobolus cylindricus,* both of which invariably form bushy cushion-like colonies, was there any appreciable formation of aerial hyphae.

Conidiospore formation by *Ceriosporopsis halima* was almost completely suppressed on asparagine agar, although a few nearly colorless and aberrant spores developed.

Pigment formation in the colonies was likewise reduced to a minimum on asparagine. With the sole exception of *Phialophorophoma litoralis* the colonies were white or hyaline in both reflected and transmitted light.

It can be stated with little qualification that asparagine is decidedly deficient as a nutrient for the development of these fungi, and that rate of radial growth is a poor index of total growth on this substratum unless it is correlated with the abundance of mycelium formation.

8. Wood Flour

Despite minor changes in resistance to fungal decay and in the chemical condition of wood induced by autoclaving (Schmitz 1919) it is reasonable to suppose that the growth of a fungus in an agar medium containing finely divided wood might indicate to some extent the wood decaying powers of the organism. *A priori,* it would seem that even active wood destroyers might grow more slowly on wood than on synthetic media containing only that constituent of the wood most readily available to them. Thus cellulose destroying microörganisms might be expected to make a more vigorous development on "purified" cellulose than on plant fibers

containing, in addition to cellulose, relatively large amounts of resins, waxes, lignin or other encrusting and protecting substances normally present in untreated woody tissues. Similarly, organisms which readily break down the hemicelluloses of the secondary wall of woody cells might presumably make a more rapid growth on synthetic substrata containing xylose and arabinose. The growth of wood destroying fungi in laboratory cultures on various wood components is probably, however, never as rapid nor vigorous as development on the normal substrata in nature. Not only are the complex factors in the ecology of the environment vastly different but also the accumulation of inhibitory metabolic products is almost inevitable in laboratory experiments. Despite these experimental difficulties, however, it is clear that growth on wood in culture gives some reasonable index of the potentialities for growth in wood under natural conditions.

The wood flour used in these experiments consisted of finely divided particles obtained by filing clear-grained sections of seasoned white pine. The resulting flour or dust was extracted for resins, washed repeatedly in solvents and finally prepared as a 0.75 per cent suspension in agar.

Growth on this medium was surprisingly rapid and vigorous in the case of all but two species, viz., *Halophiobolus opacus* and *Phialophorophoma litoralis*, colonies of which not only increased in diameter slowly but also developed scanty mycelia.

The most striking development on the wood flour substratum was made by *Peritrichospora integra*, cultures of which grew with great vigor, as indicated both by rate of radial increase (Fig. 1) and the production of a luxuriant hyphal mat. Moreover, colonies of this form after a week or ten days development produced a faint but definitely cleared zone in the medium, indicating the partial or complete destruction and dissolution of the smaller wood particles dispersed in the agar. This latter effect is indirect evidence of the utilization of lignin by the fungus, an ability which many of these fungi unquestionably possess as will be shown later.

Three of the seven species, viz., *Halophiobolus salinus*, *Peritrichospora integra* and *Halophiobolus cylindricus* exhibited a greater rate of radial growth on wood flour than on maltose agar, an interesting response in view of the relative solubility of the carbohydrates in the two media.

The color of the colonies on wood flour was quite similar to that on cellulose agar except in the case of *Halophiobolus opacus* which failed to form any discernible pigment (Table 3). *Amphisphaeria maritima* produced a very intense dark brown pigment both in the mycelium and in the substratum, a reaction similar to that produced on xylose.

Conidiospore production in cultures of *Ceriosporopsis halima* was more vigorous on wood flour than on any other artificial substratum with the possible exception of potato-dextrose agar. In addition, the spores were nearly jet black in color, an appearance intensified by their occurrence

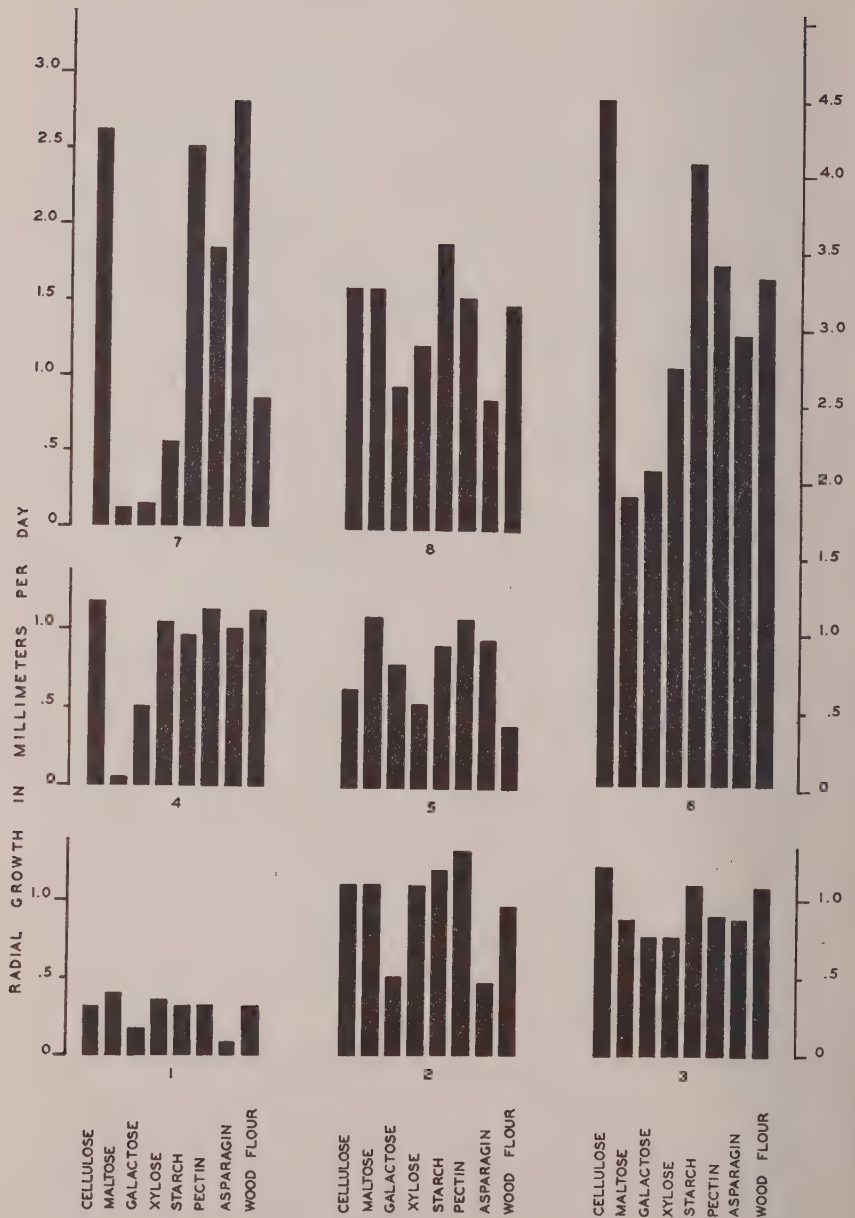

RADIAL GROWTH IN MILLIMETERS PER DAY
CELLULOSE
MALTOSE
GALACTOSE
XYLOSE
STARCH
PECTIN
ASPARAGIN
WOOD FLOUR
1
2
3
4
5
6
7
8

FIGURE 1

in dense masses. The deep black color of the spores of *Ceriosporopsis halima* also characterizes their appearance on wood substrata under natural conditions, as may be observed occasionally in freshly collected specimens of wood infected by the fungus.

EFFECT OF TEMPERATURE ON THE RATE OF RADIAL GROWTH

The influence of temperature on the rate of radial growth of seven species including the two strains of *Ceriosporopsis halima* was determined in the series of experiments graphically summarized in Fig. 2.

Reference to the collection data will show that these seven species all occur naturally in tidal waters in the latitude of or north of Cape Cod.[3] The marine environment in waters north of Cape Cod is characterized by more or less constant low temperatures, with the surface waters, except in ideally protected bays, seldom rising above 20° or 22° C. Hence, as far as the available data indicate, the present series of fungi flourish in cool or cold marine environments. Such collections as have been made of course do not preclude the possibility that the fungi are equally vigorous in warmer waters; however, no specimens have yet been examined which extend the range of these *particular seven species* south of Long Island Sound.[4]

Despite the relatively uniform temperature conditions in marine environments as contrasted to terrestrial environments, there is some evidence that variation in water temperature affects the formation of the perfect stages in at least certain species of the marine fungi. Thus, perithecia of *Halophiobolus opacus, H. salinus* and *H. longirostris* were found in relative abundance on specimens of wood collected in Provincetown Harbor, Cape Cod, during the latter part of September, 1942, whereas similar collections from the same locality made during the early part of May, 1943, showed no perithecia of these forms.

With these scanty observations concerning the ecological influence of temperature it is interesting to note the reactions of the fungi to various temperatures as indicated by their rate of radial growth in culture. A modification of the method used by Howell (1940) was followed in these experiments. From a vigorously growing colony on stock agar equal sized cubes of inoculum were cut. Three blocks of inoculum were placed equidistant on the agar in each Petri dish. One dish at a time was used

[3] *Amphisphaeria maritima, Halophiobolus salinus* and *Ceriosporopsis halima* have also been collected from Woods Hole Harbor and Long Island Sound.

[4] Specimens of rope and wood recently received from Biscayne Bay, Florida, show the presence of both the perfect and imperfect stages of different species of marine fungi.

Fig. 1. Rate of growth per day of the different fungi on various substrata. 1. *Amphisphaeria maritima.* 2. *Ceriosporopsis halima.* 3. *Halophiobolus cylindricus.* 4. *Peritrichospora integra.* 5. *Phialophorophoma litoralis.* 6. *Halophiobolus salinus.* 7. *Halophiobolus opacus.* 8. *Helicoma salinum.*

for each species for the entire series of temperatures. Data for *Ceriosporopsis halima, Halophiobolus opacus, H. salinus* and *Peritrichospora integra* are derived from two complete series of experiments.

A temperature series of 5°, 15°, 17.5°, 20°, 22.5°, 25°, and 27.5° C. was used for all seven species, and, in addition, for four species an experiment was run at 30° C. The constant temperature chambers were maintained with a range of ± 0.2° C. For the three highest temperatures heating of the chambers was effected by screened light bulbs intermittently flashing. The factor of light as judged by divers observations appears to have no influence on the rate of growth.

The results of the temperature experiments are graphically represented in Fig. 2. Without exception the data indicates that a relatively high temperature is required for optimum radial growth. Within the conditions of the experiment only three species showed an optimum temperature for growth below 25° C. *Peritrichospora integra* and *Halophiobolus cylindricus* developed most vigorously at 27.5° C., while *Phialophorophoma litoralis* grew more rapidly at 30° C. than at any lower temperature. The latter results were so unexpected that duplicate cultures were made and grown at the three higher temperatures in order to check the data. No significant change, however, could be determined in the value of the optimum temperature for development.

It will be noted that the two strains of *Ceriosporopsis halima* shows optimum temperatures differing by 2.5° C. This difference is probably within the range of experimental error particularly in view of the highly variable behavior of fungi in culture. In addition, however, a more significant cause of the discrepancy may reside in the fact that the two isolates were obtained from somewhat different ecological conditions. *Helicoma salinum* was collected from Cape Cod Bay at North Truro, Mass., while the ascospore isolation of *Ceriosporopsis halima* was secured from wood attacked by this fungus in the relatively colder environmental conditions in the harbor of Portsmouth, N. H. The general temperature relations of the two strains over the entire range of the experiment are very similar, as indicated by the fairly close correspondence of the curves shown in Fig. 2. *Halophiobolus salinus* was isolated from a specimen of wood, infected by several species of marine fungi, collected in the harbor of Corner Brook, Newfoundland. This species exhibits an optimum radial growth in culture at 25° C., a temperature far in excess of that at which the organism develops under natural conditions. *Halophiobolus salinus*, however, in this respect typifies the entire series of fungi, all of which show an optimum rate of growth in culture at temperatures considerably higher than those obtaining in their natural environment.

The temperature relations of the marine fungi as a group differ appreciably from those of the helicosporous fungi studied by Linder (1929) in which the optimum temperature was between 21° and 26° C. However, the response of *Helicoma salinum* and *Ceriosporopsis halima*, two

isolates of a form very closely related to those studied by Linder, fall within the range of his data for optimum temperature.

The consistently more rapid development of the fungi at higher temperatures suggests that their destructive action on wood and cordage might be more rapid in warm or tropical waters than in cooler northern waters. Some evidence for this is afforded by specimens of untreated rope recently examined after exposure to marine conditions off the Florida coast.[5] Such material shows an abundant growth of various benthonic organisms, algae and various invertebrates, and, beneath this surface growth a vigorous fungal flora invading the cordage fibers. The death and very rapid bacterial decomposition of organisms in the surface growth on wood and cordage in warmer waters perhaps serves to stimulate the development of marine fungi through the release of various readily available nutrients. These factors in conjunction with the higher temperatures appear to accelerate the degradation of cordage fibers by fungi. Histological evidence and tensile strength measurements, however, are not yet available to allow a critical evaluation of the relative rates of decomposition of cordage by marine fungi under divergent natural conditions of temperature.

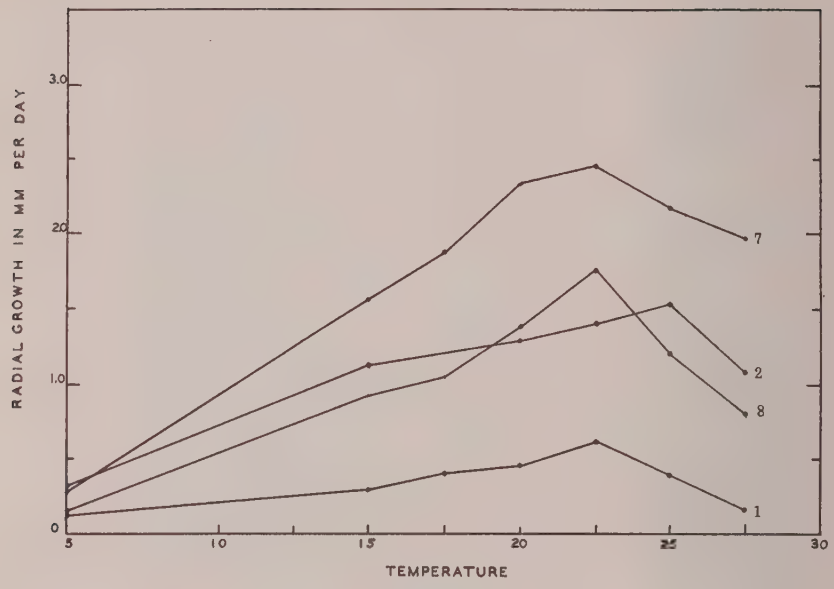
At the lower end of the temperature range it will be noted that all the species grow to an appreciable extent at 5° C., and, in the case of *Halophiobolus salinus*, the rate of growth is relatively high at this temperature. Although no measurements were made at temperatures lower than 5° C., cultures maintained between 0° and 1° C. showed some slight but nevertheless appreciable growth. From the available data it is evident that the marine fungi, despite relatively high temperature optima, are capable of growth and development at temperatures no higher than those of arctic oceanic waters.

TABLE 4. INFLUENCE OF TEMPERATURE ON COLOR OF COLONY AND SPORE PRODUCTION. COLONIES 9 DAYS OLD ON MALT EXTRACT AGAR

	Temperature Centigrade			
	5°	15°	20°	25°
Amphisphaeria maritima	Very light brown 0	Light brown 0	Light brown 0	Light brown 0
Peritrichospora integra	White 0	White 0	Greenish gray 50	Greenish gray 0
Ceriosporopsis halima	White 0	Greenish gray 25	Greenish gray 50	Greenish gray 50
Halophiobolus opacus	White 0	White 0	White 0	White 0
Halophiobolus salinus	White 0	White 0	Yellow brown 0	Yellow brown 0

In regard to the relation between colony color and temperature, observations were made on the five species enumerated in Table 4 from cultures grown at temperatures of 5°, 15°, 20° and 25°. It will be noted that in general the color production of the mycelia increases with increase in temperature. The chromatic qualities of the pigment formed by a par-

[5] Specimens supplied through the courtesy of Dr. Robert Williams, Assistant Director of the Marine Laboratory of the University of Miami, Coral Gables, Florida.


RADIAL GROWTH IN MM PER DAY
3.0
2.0
1.0
0
5
10
15
20
25
30
TEMPERATURE
7
2
8
1

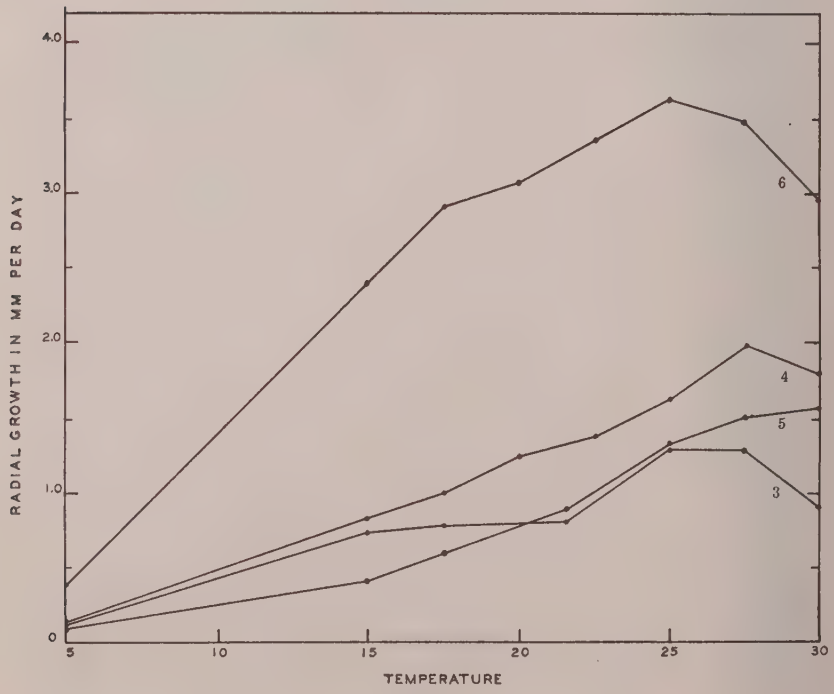

RADIAL GROWTH IN MM PER DAY
4.0
3.0
2.0
1.0
0
5
10
15
20
25
30
TEMPERATURE
6
4
5
3

FIGURE 2

ticular species, however, show no change, the difference being merely one of intensity or amount. At low temperatures the colonies of these forms were all white or hyaline in appearance with the exception of *Amphisphaeria maritima* which developed a faint tinge of its characteristic buff brown color even at 5° C.

Conidiospore production in cultures of *Ceriosporopsis halima* increased noticeably with increasing temperature. Sporulation on the malt extract agar used in experiments on the effect of temperature was never more than approximately 50 per cent of the maximum observed on the most favorable media and no difference was detectable in spore formation on malt extract between 20° and 25° (Table 4).

EFFECT OF VARYING HYDROGEN ION CONCENTRATION

The pH of normal sea water from the open ocean varies in general between 8.1 and 8.3 (Harvey 1928). Much greater fluctuations, however, may be observed in the coastal waters of bays, lagoons, and estuaries, habitats in which the marine fungi have not uncommonly been found. The vigorous development of algae in rocky pools and sheltered lagoons may result in daytime pH values as high as 8.6, or, if an abundant growth of *Ulva* is present, as high as 9.7. The variations of pH under such conditions are largely dependent on changes in the CO_2 content resulting from active photosynthesis in the phytoplankton.

Although the pH of sea water may be very different from the biologically effective pH *in* the decaying wood or bottom deposits, it is nevertheless true that strictly aerobic organisms infecting such material must make their initial if not most of their subsequent development in a medium of the same pH as the surrounding sea water. Inasmuch as the ascospores and conidiospores of marine fungi are released, disseminated, and germinated in sea water, it is clear that their initial development occurs at pH values within the range of that for sea water. This range, as above noted, is of considerable extent in coastal waters, such as those in which the fungi are most frequently found.

The influence of the pH of the medium on the rate of radial growth was determined for five species including the two isolates of *Ceriosporopsis halima*. The results of these experiments are shown in Fig. 3 and are of interest primarily in illustrating the physiological adaptation to the marine environment which had occurred in these organisms as indicated by their rapid rate of growth at a relatively high pH. In Part I of this study it has been shown that certain of these forms exhibit morphological modifications to the aquatic environment. The experiments on the in-

Fig. 2. The effect of temperature on the rate of radial growth. 1. *Amphisphaeria maritima.* 2. *Ceriosporopsis halima.* 3. *Halophiobolus cylindricus.* 4. *Peritrichospora integra.* 5. *Phialophorophoma litoralis.* 6. *Halophiobolus salinus.* 7. *Halophiobolus opacus.* 8. *Helicoma salinum.*

fluence of hydrogen-ion concentration clearly show a corresponding physiological modification.

Five per cent malt extract agar was used as the culture medium in determining the effect of hydrogen-ion concentration on the rate of growth. This substratum was chosen because it provided a good general medium for the growth of all species. After sterilization, the agar consistently gave a reaction of pH 6.5. The sea water used was not buffered and pH changes during the course of the experiment were noted. These pH changes in the agar were not great and always tended toward the value of 6.6. The greatest change in reaction occurred in media with an initial pH of 9.2, such media registering a decline to 8.6 during the six to nine day experiments. The pH values shown in Fig. 3 are the initial readings at the time of inoculation. Cultures were maintained at temperatures between 22° and 24° C.

Reference to Fig. 3 will show that all the species except *Amphisphaeria maritima* exhibit an optimum growth at a pH of 7.4 or higher. The optimum for *Halophiobolus opacus*, 8.4, is the highest in the entire group. *Amphisphaeria maritima* developed best at 4.4, but shows remarkably little variation over the entire range between 4.7 and 8.4.

The behavior of *Halophiobolus opacus*, *H. salinus* and *Peritrichospora integra* are interesting in view of the fact that these species failed to make any growth at low pH. This behavior seemed so unusual that numerous efforts were made to induce these forms to grow in acid media, but no growth occurred in cultures of *Peritrichospora integra* and *Halophiobolus opacus* at a pH below 4.7. *Halophiobolus salinus* failed to grow below pH 4.4 but above this its growth curve rapidly rises (Fig. 3). The very rapid increase in the rate of growth with such slight change in pH is probably caused by the inactivation of certain enzyme systems in this organism at a pH slightly below 4.7.

All five species represented in Fig. 3 show a decline in the rate of growth above pH 8.4, which is approximately the upper limit of the pH for sea water under normal conditions.

A double peak in the growth curve was obtained from the data from *Halophiobolus opacus*. This response to varying pH is not uncommon in fungi and was shown by Walpert (1924) in the case of certain wood destroying Basidiomycetes and by Linder (1929) in the helicosporous Fungi Imperfecti.

An interesting comparison may be made between the reactions of the marine *Helicoma salinum* and the terrestrial wood destroying helicosporous forms, *Helicoma Mulleri* and *Helicoma Curtisii*, studied by Linder (1929). Both of the latter species developed most vigorously at pH 4.2 and 4.4, respectively. *Helicoma salinum* on the other hand makes its optimum growth between pH 7.4 and 8.2. The terrestrial heliocosporous fungi, moreover, very rapidly declined in their rate of radial growth above pH 7.0. The contrast in response to hydrogen-ion concentration of these

morphologically related forms is another example of the physiological modifications which have occurred in the transition from terrestrial to marine environment.

Although more extensive and more exactly controlled experiments than those which have been described should be undertaken to clarify the pH relations of the marine fungi, the data summarized in Fig. 3 represent their general response to varying hydrogen-ion concentrations. The upper limits of their pH tolerance have not been accurately determined in this study, although it clearly lies well above that for the majority of fungi, especially those terrestrial wood destroying forms which have been studied in this particular phase of physiological behavior.

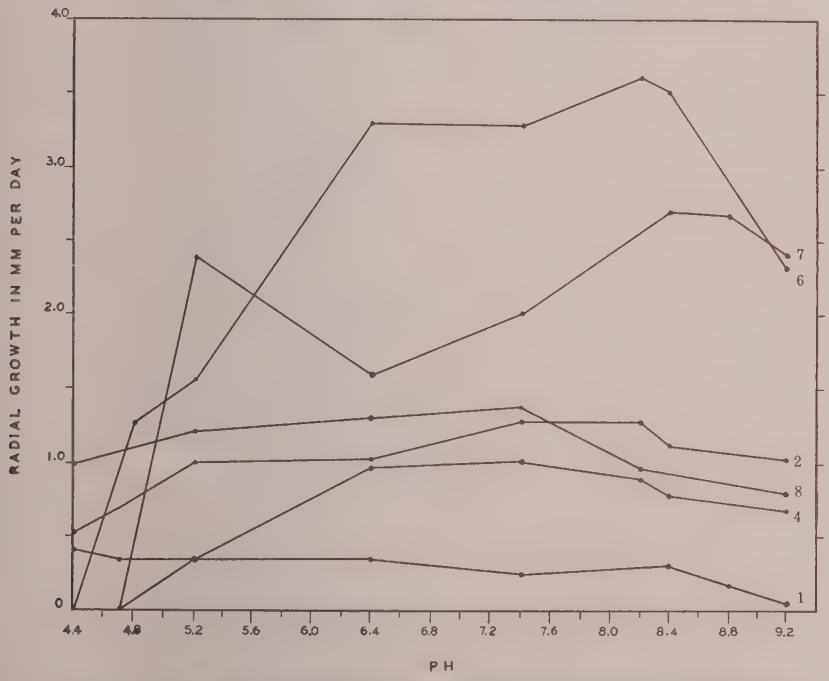


Fig. 3. The effect of hydrogen-ion concentration on the rate of radial growth. 1. *Amphisphaeria maritima.* 2. *Ceriosporopsis halima.* 4. *Peritrichospora integra.* 6. *Halophiobolus salinus.* 7. *Halophiobolus opacus.* 8. *Helicoma salinum.*

BEHAVIOR OF MARINE FUNGI IN THE NATURAL SUBSTRATUM

Inasmuch as these fungi have been isolated from submerged wood and cordage, such materials as well as other substances of similar chemical composition may be regarded as their natural substrata. Hence, substrata for their development are provided for by a great variety of organic

detritus of plant origin either naturally occurring as in sediments, or modified by man as in wood, cordage, etc.

The existence of actively growing fungi in wood or cordage submerged for periods of a month or more, in tidal water, may be satisfactorily demonstrated by collecting small specimens of such material and placing them in previously sterilized vigorously aerated sea water.[6] These conditions allow the fungi to develop their mycelia on the surface as well as within the substratum. The appearance of fungal hyphae, under these conditions, occurred in the great majority of samples which the author has examined, viz., fragments of piling, submerged stumps, portions of "water logged" driftwood collected along the coast, and specimens of cordage of various fiber types such as hemp, jute and sisal. Frequently the examination of fungal-infected material under the binocular microscope will reveal the presence of perithecia of the various types described in Part I of this study. Scrapings from the surface growth on submerged wood and cordage commonly contain the helical spores of some members of the helicosporous species of marine fungi.

Gross examination of wooden piling which has been continuously submerged in sea water shows that the surface layers of the wood become soft and commonly discolored. The softened outer portions easily disintegrate and erode, thus continually exposing fresh surfaces for attack by the agents of decomposition. Commonly, in tidal waters possessing sufficient current to carry particles in suspension, the erosive action is greatest near the so-called mud line, bringing about the formation of a "constricted" portion just above the region where the piling enters the sand, silt, mud or other bottom deposit. A similar "constricted" portion, also, not uncommonly develops at the high tide zone, where wave or current action at high water brings about a differential rate of erosion on the wood that has been softened by fungi. In this way, the erosion and wearing of piling appears to be due to mechanical erosive action alone, whereas the essential cause of the localization of erosion in the two zones is ultimately biological in origin.

The cause of the softening and weakening of wood and cordage in sea water may be ascribed to either bacteria or fungi on the basis of macroscopic examination of affected material. Histologic study of such specimens, however, reveals the fact that the dominant cause of decay is fungal in nature. Plate VII, figures 2 and 5 show the action of marine fungi in their characteristic mode of attack on the secondary walls of plant fibers. Radial longitudinal sections of wood exhibiting symptoms of decay reveal the presence of fungal hyphae deep within the tissue, whereas the presence of appreciable numbers of bacteria can be demonstrated only in the outer layers where fungal action has preceded their entry.

Although the precise mode of action of these wood-destroying fungi is

[6] Aeration is very important for the satisfactory development of marine organisms in sea water in laboratory cultures.

at present being more extensively studied, it is of interest here to note the physical changes resulting from their development in wood and cordage, particularly in terms of the finer structure of the cell wall. The hyphae of marine fungi, as well as of terrestrial wood destroying fungi, invade the tissue in three diverse ways: (1) by penetrating the wood radially by means of the wood rays, traversing the tissue by passing through the end walls of ray cells, (2) by growing directly through the cell walls of tracheids or fibers and (3) by penetrating and ramifying the central layers of the secondary wall.

The development of mycelia in the rays of wood may be easily demonstrated in radial longitudinal sections of favorable material. The hyphae in the ray cells are frequently large and heavily pigmented and the greatest depth of decay or penetration by these hyphae is commonly in the wood rays. From the ray cells, hyphal branches are occasionally found which extend into the lumina or cell walls of adjoining tracheids, fibers or wood parenchyma cells.

In wood attacked by marine fungi radial longitudinal sections, favorably stained,[7] show the development of hyphae which penetrate the walls of adjoining cells, passing from lumen to lumen transversely through the cell walls. Such hyphae may develop unidirectionally in the wood for considerable distances, not only from cell to cell, but from growth ring to growth ring, thus rapidly spreading the mycelium in the tissue. For the most part, those hyphae which pass directly from cell to cell tranversely through the walls narrow down to a tenuous thread as they penetrate the cell wall and particularly the intercellular substance, much as do the hyphae of terrestrial wood destroying fungi such as those forms figured by Hubert (1924) and others. Immediately after passing through the wall into the adjacent lumen, the hyphae enlarge, thus giving rise to a series of alternately constricted and inflated segments.

More interesting, though more difficult to observe, are the hyphal threads which operate within the secondary walls of the cells. These are most clearly demonstrated by proper staining techniques in the thick-walled tracheids of conifers. Such hyphae grade down to a minute size, and, as far as present observations have gone, follow the orientation of the cellulose macrofibrils in a manner apparently identical with that described by Bailey and Vestal (1937) for certain terrestrial wood destroying fungi. Within the secondary walls, and particularly noticeable in thick-walled late wood tracheids of coniferous woods, the longitudinally oriented hyphae dissolve elongated cavities of varying sizes. Such cavities when viewed in transverse sections of wood give the appearance shown in Plate VII, figures 2 and 5.

In order to obtain additional information as to the mode of action on wood of particular members of these fungi, a series of cultures was made

[7] Methyl violet and Bismarck brown after the method of Hubert (1922) have been found particularly useful in these studies.

containing radial sections of wood embedded in agar. The sections were cut at a thickness of approximately 30 μ from a selected block of white pine heartwood. The wood was given no chemical pretreatments but sectioned after soaking in cold water and the sections dried and sterilized. Cultures were prepared by adding the dry wood sections to the plates after pouring. The sections were pushed to the bottom of the liquid agar and there embedded. This made observations possible directly through the dish. The direct action on wood of ten species of the fungi was studied in this manner.

The cultures containing wood sections were kept successfully for six months without visible contamination or serious water loss from the agar plates. The thin sections were then cut out, completely freed from agar by boiling water, stained and mounted. In every culture prepared in this manner the cell walls of the wood exhibited penetration and degradation to varying degrees by fungal hyphae.

These experiments, although not refined in method, demonstrate beyond question that the ten species investigated by this technique are capable of attacking the three major constituents of the cell wall and intercellular substance, viz., cellulose, lignin, and pectic compounds. Further experiments of this type are now in progress in a more extensive study of the wood and fiber destroying powers of this group of fungi.

The significance of marine fungi as agents of economic importance is perhaps best exemplified by their ability to attack cordage which has been exposed continuously or for long periods to sea water. The rough outer surfaces of rope, and the presence of innumerable and minute indentations in the fiber strands present extensive surface areas to which spores may become attached and infection established. Moreover, the physical structure of rope is such that fungal hyphae penetrate and ramify in it with comparative ease, and a rapid decline in tensile strength of the fibers results primarily from hydrolysis of the cellulose component of the fiber walls.

In the summer of 1942, the writer collected several samples of untreated manila hemp rope (approximately one-quarter inch diameter) which had been totally submerged for six months in the water of Woods Hole harbor. This material had become somewhat softened and blackened on the outer surface but otherwise appeared in good condition. When a strain was applied, however, the rope failed under a tension of from 15 to 20 pounds. A microscopic study of the outer fibers of the rope showed the presence of innumerable hyphae, the larger of which were darkly pigmented. Under the binocular microscope portions of the fiber strands exhibited great numbers of partially embedded black perithecia of *Halophiobolus salinus*, in some areas as many as 200–300 perithecia per linear inch of rope length.

Similar, though not as severe, attack on rope has been found in material collected in several other Massachusetts harbors north of Cape Cod. Of the perithecia found on rope, those of *Halophiobolus salinus* are the

most frequent and, judging by its common occurrence and rapidity of growth as well as its cellulose digesting powers, this is probably the most destructive and economically significant species in the degradation of cordage by fungi in the sea.

The formation of perithecia deep within the substratum presents indisputable evidence that certain of these fungi are capable of breaking down lignin. The perithecia of *Halophiobolus longirostris*, (Plate VII, figs. 3, 4) are characterized by the development of enlarged pockets within the wood, and in the formation of such cavities all the constituents of the wood are broken down. Experimental as well as observational evidence that lignin is attacked has been obtained by culturing the fungi on an agar medium containing the finely divided lignin residue of degraded wood. For this purpose a relatively unaltered lignin was available from certain archaeological specimens which chemical analysis had shown to have undergone no change in lignin content but an almost complete loss of cellulose (Jahn and Harlow 1942). This lignin-rich material was triturated in a mortar and dispersed in agar, thus forming a medium of semi-transparent consistency. All of the fungi developed slowly on this medium giving rise to relatively sparse mycelia. After an incubation of four to five weeks, however, certain species produced partially cleared zones in the lignin agar. The cleared zone, indicating dissolution of minute particles of the lignin, was particularly evident in the case of *Phialophorophoma litoralis*.

Although the relative significance of bacteria and fungi in the degradation of wood and cordage in sea water has not been quantitatively evaluated, it seems clear to the writer from the evidence presented in this study that the marine cellulose destroying fungi are the more significant organisms, particularly in the early stages of the decomposition processes.

SUMMARY

1. The physiological behavior of seven species of marine fungi, obtained from ascospore isolations, has been studied particularly in regard to their response to temperature, hydrogen-ion concentration and rate of growth on artificial substrata.

2. Growth of the fungi on media of varying salinity shows that these forms are adapted to the saline environment of the sea. Tolerance of relatively high salt concentrations is demonstrated by their growth in sea water of three times normal salinity.

3. When grown on sea water agar containing separately cellulose, maltose, galactose, xylose, starch, pectin, asparagine and wood flour, growth as measured by radial increase in the colonies was most rapid on cellulose, pectin and starch, respectively. Growth was vigorous and fairly rapid on wood flour agar. Galactose induced the formation of abnormalities in both the hyphae and spores of certain forms. Asparagine supported considerable radial growth but the mycelia produced on this sub-

stratum were very sparse and nearly devoid of aerial hyphae. Rate of growth on the various substrata was measured in terms of radial increase; the extent of production of hyphae by the colonies, however, was also considered in evaluating the availability of the substratum.

4. Forms which normally produce conidiospores in culture sporulated most heavily on cellulose, wood flour and pectin.

5. Color of the colonies varied widely in response to the substratum; the greatest frequency of pigmentation in the group as a whole, however, occurred on pectin.

6. The most favorable temperature for growth on complex synthetic media was between 22.5° and 27.5°. Several species grew most rapidly at 27.5° C. and one form at 30° C. All the species cultured made an appreciable growth at 5° C. The relatively high optimum temperatures for growth in culture, contrast strongly with the temperature of the natural environment of the sea.

7. With one exception the entire group developed best in media with an initial pH above 7.6 and growth was definitely unfavorable in acid media. Two species failed to develop at pH 4.6 or below. The response to hydrogen-ion concentration may be logically interpreted as a physiological modification to marine conditions.

8. All the marine fungi described in these investigations were isolated from specimens of wood or rope exposed for varying periods to partial or complete submergence in salt or brackish tide waters. Histological examination of their natural substrata shows that they penetrate and ramify in the cell walls of wood and cordage fibers inducing decay by enzymatic hydrolysis of the cellulose and other constituents of the cell wall. Their mode of action in the enzymatic hydrolysis of woody tissues is quite comparable to that of terrestrial wood destroying fungi. Laboratory experiments under controlled conditions demonstrate their ability to attack the various constituents of wood in artificial culture.

Extensive studies are now in progress to determine the enzyme formation by these fungi and to measure their cellulose and lignin resolving power.

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EXPLANATION OF PLATE VII

Fig. 1. Radial longitudinal section of a fragment of black oak piling infected with *Halophiobolus opacus*. The outer layers of the wood are highly degraded by fungal hydrolysis. Note the elongated ascospores borne in the superficial perithecia of the fungus. Specimen number 14. × 50.

Fig. 2. Transverse section of the outer edge of a hard pine test block showing advanced stages in fungal hydrolysis of the cell wall caused by *Ceriosporopsis halima*. The enzymatic activity of the hyphae is almost exclusively confined to the central layers of the secondary wall. The more highly lignified inner and outer layers of the secondary wall are relatively unaffected at this stage of decomposition. Specimen number 11. × 420.

Fig. 3. Transverse section of a spruce test board attacked by *Halophiobolus longirostris*. Note the long neck of the deeply embedded perithecium. Specimen number 22. × 50.

Fig. 4. Radial longitudinal section of the same wood specimen shown in Figure 3. Note the complete destruction of cell wall substance in the region surrounding the perithecium. Within the tracheids of the wood are spherical inflated cells produced by hyphae in the lumina. Specimen number 22. × 50.

Fig. 5. Transverse section of hard pine test block attacked by *Ceriosporopsis halima* showing early stages in the breakdown of the cell wall by hyphal action. The area shown is two growth rings in from the outer exposed surface of the wood. Note the restriction of hyphal cavities to the central layers of the secondary wall. Specimen number 11. × 230.

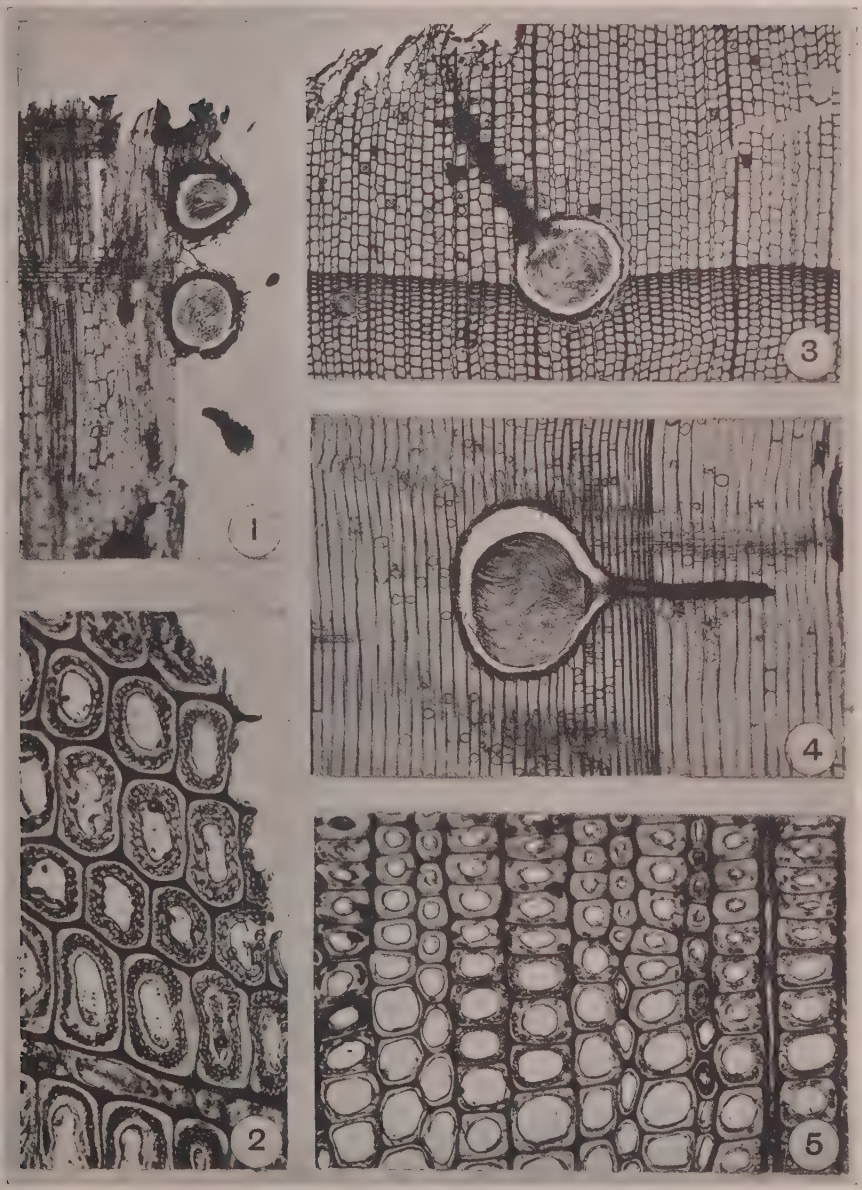

PLATE VII

1(3): 469–481 FARLOWIA January, 1944

STUDIES IN THE GENUS ZYGOSACCHAROMYCES I. TRANSFER OF PELLICLE-FORMING YEASTS TO ZYGOPICHIA [1]

WALTER J. NICKERSON [2]

That the taxonomy of even the sporogenous yeasts is in an unsatisfactory state is a statement admitting of little debate. The important work of Stelling-Dekker (1931) served to bring considerable order out of chaos, but the need is still felt for monographic treatments of the various genera of yeasts. In considering only the organisms of which cultures were available to her, Stelling-Dekker followed a practice which has much in its favor. Practically, however, it results in almost complete neglect of species not included in the monograph by all except specialists in a particular group. One function of a monographer is the critical consideration of as many of the forms assigned to a group as is possible. Since it is manifestly impossible for one person to have access to cultures of all the species in a large genus, the monographer is forced, by necessity, to make decisions based solely upon descriptions in the literature. However, the scanty descriptions in some of the older literature are frequently valueless, and the names should be cleared from the books as *nomina nuda*, *nomina dubia*, etc., as the case may be, unless an authentic culture is at hand for a redescription.

The yeasts are a poorly defined assemblage of fungi, chiefly Ascomycetes, with a monophyletic standing in the *Endomycetaceae* favored by some workers, and a biphyletic treatment embracing the *Exoascaceae* sponsored by others. It seems best to think of a "yeast-state" much as one today thinks of a "colloidal-state" rather than of "a colloid." This "no-man's land," which does not even grant its workers a distinctive name (!), is one cultivated chiefly by techniques borrowed from bacteriology and mycology as the need may arise. In the past, adherence to the International Rules of Botanical Nomenclature has only too frequently been neglected. And a somewhat exclusive adoption of bacteriological techniques has resulted at times in the neglect of valuable taxonomic tools such as the range of variation, morphology of spores and of asci, geographical distribution, etc.

In presenting this paper as the first in a series intended to constitute a monograph of the genus *Zygosaccharomyces*, the author is aware of some, at least, of the difficulties and limitations imposed by the very nature of the organisms involved. Use must be made of any distinguishing

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[2] The writer, now serving with the Army of the United States, wishes to thank Drs. D. H. Linder and W. L. White for their help on problems of nomenclature, Drs. Mrak and Wickerham for kindly supplying some of the cultures used, and Dr. H. W. Anderson, University of Illinois, for sending type slides of *Z. Chevalieri* var. *Andersonii* with which comparisons were made.

character available, be it morphological or physiological, for the organisms in question do not fall into clearly defined, discrete species, but present a picture of individuals more or less concentrated into groups (species) with gradations in all directions away from any given center of concentration. A character which shows a normal statistical distribution is in general of little separatory value taxonomically. For instance, if spore sizes within a genus fall along a normal distribution curve when graphed, then this particular character will not serve alone to differentiate groups. On the other hand, a character exhibiting discontinuous variation within a genus serves readily to divide a genus into two groups: i. e., those that have and those that have not. The "centers of concentration" mentioned above grow out of the overlapping of the curves of discontinuous variation. Possibly no microbiologist could be found who would seek to conceal the fact that the species concept in regard to yeasts is a fairly intangible thing; but for practical purposes, possibly to parallel or interweave with the development of a comparative biochemistry, it is essential that we be agreed upon principles of intra-generic classification. The inter-specific gradation which exists must be recognized as such and not serve to cause the creation of numerous "poor" species. The existence of strains of microorganisms is clearly recognized by all as a difficult question taxonomically; a strain is essentially any isolate of a micro-organism that is in any way distinguished from its "parent" species; usually it is distinguished in some comparative way, as larger, smaller, more vigorously fermenting, etc. However, in the case of some micro-organisms, where parasitism is involved, one is able to distinguish clearly among forms identical with respect to the usual morphological and physiological criteria. See Leonian and Lilly (1943) for an interesting discussion of the species-complex problem in microbiology. Perhaps the existence of strains serves to indicate the direction in which the production of discontinuous variation within a genus is progressing with time, and perhaps it is a result of an improvement in our ability to make distinctions.

The subgenus *Zygosaccharomyces* Barker, following Klöcker (1924) and Stelling-Dekker, is rather large, with the literature on it scattered. Approximately 60 species have been described since Barker (1901) founded the genus. To date, Stelling-Dekker's treatment has been most complete with a consideration of some 20 species. During the past 5 years the writer has gathered together some 90 cultures including about 40 of the described species. From these cultures, a few stand out by reason of their *not* meeting the generic requirements of *Zygosaccharomyces*. While the writer, in this paper, does not intend completely to delimit the genus, he is in thorough agreement with Klöcker and with Stelling-Dekker in excluding all organisms that form films promptly in ordinary sugar-containing liquid media. Before taking up the problem of the relationships existing among species properly belonging to *Zygosaccharomyces*, the writer hopes to simplify the problem by transferring

forms which do not meet the requirements of the genus. The remainder of this paper will be devoted to a discussion of 5 pellicle-forming yeasts that have been assigned at one time or another to *Zygosaccharomyces*, but which should be classified in *Zygopichia*.

METHODS

Sources of the organisms studied in this paper are listed under the species concerned in the section on taxonomy. Stock cultures were carried as stab-cultures in wort agar (Difco) with 1% added Bacto-agar. Culture studies employed wort and wort agar slants; for liquid cultures a synthetic medium described later in the paper was also used with the addition of 1.5 gm. Bacto-asparagine per liter. Measurements on vegetative cells were made, using an ocular micrometer, after 48 hours growth; averages of the measurements are reported. Sporulation occurred readily by seven days on wort agar slants except in the case of *Z. Chevalieri*, H-175, which responded to culture on Sabouraud's dextrose agar (Difco) with a 5% addition of *Aspergillus* filtrate prepared according to Nickerson and Thimann (1943). Fermentation tests were performed with Durham tubes; if dextrose, fructose, and mannose were not fermented, no other sugar was investigated. Nitrate utilization was studied in a liquid medium using KNO_3 as the sole nitrogen source; a test for nitrite was also performed; a discussion of the value of examining solely for the presence of nitrite will be found later in the paper. Ethanol utilization was studied using the synthetic medium referred to but omitting glucose, peptone, and asparagine; recently boiled absolute alcohol was added aseptically after autoclaving to give the medium a final concentration of 2%. A discussion of adaptation and tolerance to increasing solute concentrations, including ethanol, will be found later in this paper. Gelatin liquifying ability tested with stabs and plates of wort gelatin (pH 4.8) and malt extract (Difco) gelatin (pH 5.8). Maximum temperature for growth studied in wort and in the synthetic medium.

EXPERIMENTAL

In view of the findings of Baars (1930) on the sulfate reducing bacteria, wherein he showed that *Vibrio estuarii* is merely a salt-adapted form of *Spirillum desulfuricans*, it was thought worthwhile to investigate some of the yeasts discussed in this paper. As will be pointed out, *Zygosaccharomyces Guilliermondi* is quite similar to *Zygopichia Chevalieri*, being distinguished chiefly by its reported ability to grow in media containing 25% NaCl. Since the possibility exists, at least, that *Z. Guilliermondi* is merely a salt-adapted form of *Z. Chevalieri*, the following experiments on adaptation of various members of *Zygopichia* were undertaken.

To a basic medium consisting of: 3.0 g. $(NH_4)_2SO_4$, 2.0 g. KH_2PO_4, 0.25 g. $CaCl_2$, 0.25 g. $MgSO_4$, 20.0 g. glucose, 2.0 g. Bacto-peptone, 0.10 g.

yeast extract, and distilled water to make 1 liter, various amendments were added as indicated in the respective experiments. The usual methods for quantitative measurement of yeast growth—counting of cells or weighing of cells—are difficult to use with these film-forming species; in most cases only a qualitative statement is given as to the extent of growth; in a few cases, quantitative measures of metabolic products—chiefly total acid production—have been made. All experiments were kept at a room temperature of about 20° C.

In tables 1–3 are found data obtained from duplicate experiments on subjecting yeasts to various environments. All cultures were inoculated from vigorous growths on wort agar and observed at intervals for pellicle formation; usually the lower concentrations supported a good growth. After varying intervals of time, higher concentrations not showing growth were inoculated from the next lower concentration showing a pellicle; a sterile flask of the higher concentration in question was also inoculated—data reported are based on the inoculation into this previously sterile flask.

The concentrations employed for the various amendments are calculated in three ways in table 1: as per cent final concentration, as molarity,

TABLE 1—SALT TOLERANCE

Total NaCl concentration	*Z. Chevalieri* M.1	*Z. Chevalieri* v. *Andersonii* H. 177
2% 0.34 M 0.61 M	pellicle in 5 days.	sediment only, 10 days.
5% 0.85 M 1.53 M	pellicle in 10 days.	sediment only, 25 days.
8% 1.36 M 2.45 M	no growth in 15 days; pellicle in 1 day when inoculated from 5%.	no growth in 25 days; no growth in 5 days when inoculated from 5%.
10% 1.7 M 3.06 M	no growth in 15 days; pellicle in 3 days when inoculated from 8%.	
15% 2.55 M 4.59 M	no growth in 20 days; faint sediment in 5 days when inoculated from 10%; no pellicle.	
20% 3.4 M 6.12 M	no growth in 25 days; no growth in 10 days when inoculated from sediment of 15%.	

and as molarity $\times$ 1.8 to represent the effective molarity for the development of osmotic pressure by a binary electrolyte. It is indicated in table 1 that the strain of *Z. Chevalieri* used, while able during growth to be-

TABLE 2—SUGAR TOLERANCE AS SHOWN BY PELLICLE FORMATION

Organism	Total concentration of glucose							
	2% 0.11M	6% 0.33M	10% 0.55M	14% 0.77M	18% 0.99M	22% 1.22M	30% 1.65M	42% 2.33M
Z. Chevalieri v. *Andersonii*	2 days	2 days	2 days	2 days	2 days	3 days	3 days	7 days

come adapted to increasing concentrations of solute, has an upper limit to this adaptation in the region of 4M solute concentration. Thus, while *Zygosaccharomyces Guilliermondi* is probably just a salt-adapted form of *Z. Chevalieri*, there is a difference in their salt tolerances of about 3M effective solute concentration. Under the conditions of the experiment and with the strain employed, *Z. Chevalieri* var. *Andersonii* exhibited no ability to form a pellicle on even 2% NaCl. By 10 days it had formed good sediment, but no trace of pellicle.

In the alcohol series (table 3), each of the three organisms formed a

TABLE 3—ALCOHOL TOLERANCE

Total alcohol concentration	*Z. Chevalieri* var. *Andersonii* H.177	*Z. Chevalieri* M.1	*Z. farinosa* ATCC 2252
2% 0.43 M	pellicle in 6 days.	pellicle in 5 days.	pellicle in 6 days.
5% 1.09 M	no growth, 14 days; pellicle on inoc. from 2% in 1 day.	pellicle in 8 days.	pellicle in 6 days.
10% 2.17 M	no growth, 16 days; pellicle in 5 days on inoc. from 5%.	no growth, 10 days; pellicle in 2 days on inoc. from 5%.	pellicle in 6 days.
15% 3.26 M	no growth, 18 days; pellicle islands in 5 days on inoc. from 10%.	no growth, 12 days; pellicle in 6 days on inoc. from 10%.	no growth, 10 days; pellicle in 2 days on inoc. from 10%.
20% 4.34 M	no growth, 18 days; no growth 5 days on inoc. from 15%.	no growth, 16 days; faint sediment only on inoc. from 15%.	no growth, 15 days; pellicle islands in 5 days on inoc. from 15%.

well-developed pellicle that began to ascend the walls of the flask or tube shortly after being formed. Castelli used this pellicle phenomenon as a characteristic serving to differentiate *Z. chiantigiana* from *Z. Chevalieri* but it is evident that such an ability is common to most, if not all, members of the genus.

TABLE 4—A COMPARISON OF MEMBERS OF *Zygopichia*

	Z. Chevalieri	*Z. Chevalieri* v. *Andersonii*	*Z. Chevalieri* v. *Barkeri*	*Zygosacch. Guilliermondii*	*Z. farinosa*	*Z. chiantigiana*
Pellicle in liquid media	+	+	+	+	+	+
Fermentation	−	−	−	−	+ d, l, m	−
Conjugation	heterogamic	heterogamic	physiol. heterogamic	heterogamic	iso- and heterogamic	heterogamic
Spore shape	hat-shaped or spherical	spherical and smooth	spherical and smooth	hat-shaped or spherical	spherical or oval	spherical or flattened
Spore size	± 2.5 μ	± 2.0 μ	± 4.3 μ	± 2.0 μ	2 x 3 μ	± 2.8 μ
Cell size in wort 2–3 days old	3–4 x 4–8.5 μ	4 x 6.5 μ	4–5 x 5–7.8 μ	3–5 x 6–9 μ	2–5 x 4–16 μ	2.4–3.6 x 7.2–9.6 μ
Mycelium on agar	+	−	−	+	−	+
Gelatin liquefaction in days	+21	+21	*	−20	−60	−60
Nitrite test	−	−	*	*	−	−
Ethanol utilization; pellicle formation	+	+	*	*	+	+
Max. temp. for budding in wort in °C.	42–43	39–40	32.5	34	*	37
Remarks:	cells often 1.5–2.2 x 12–22 μ		cells elongate in old culture	grows in presence of 25% NaCl	cells soon become elongate	central oil globule in spores

* *No data*

ZYGOSACCHAROMYCES vs. ZYGOPICHIA

Following Stelling-Dekker and Klöcker, the distinctions between *Zygosaccharomyces* and *Zygopichia*, genera having gametic conjugation preceding the formation of spores, are as follows:

Zygopichia: in wort a dry, dull pellicle within a short time (24–72 hours) after inoculation; spores angular, hemispherical, hat-shaped, or spherical.

Zygosaccharomyces: no pellicle in wort, or at most a soft, slimy pellicle when fermentation is nearly complete, which is a considerable time (2–3 weeks or more) after inoculation; renniform, hat-shaped, or spherical spores.

ZYGOPICHIA Klöcker, Die Gärungsorganismen, 3 Auflage, Berlin-Wien. 1924.

The genus was established by transferring *Zygosaccharomyces Chevalieri* Guilliermond to it as the type. It bears the same relation to *Pichia* that *Zygosaccharomyces* bears to *Saccharomyces*. In addition to the generic characters brought out in the above comparison, there are the following: fermentation, none or only very weak, nitrite tests negative, nitrate assimilation poor, cells of varying shape with a tendency towards pseudomycelial formation.

KEY TO THE SPECIES OF ZYGOPICHIA[3]

1. On wort, a thin, smooth pellicle; no fermentation
   2. Spores hat-shaped; pseudomycelium formed on wort agar **1. Z. Chevalieri**
   2. Spores smooth only; no pseudomycelium formed
      3. Spores small, about 2.0 μ diameter; heterogamic conjugation. **2. Z. Chevalieri v. Andersonii**
      3. Spores large, greater than 4.0 μ diameter; gametes morphologically similar **3. Z. Chevalieri v. Barkeri**
1. On wort, a thick, dry, wrinkled pellicle; fermentation of glucose, fructose, and mannose only ..... **4. Z. farinosa**

1. Zygopichia Chevalieri (Guilliermond) Klöcker, Die Gärungsorganismen, p. 289–290, Berlin-Wien. 1924.

Zygosaccharomyces Chevalieri Guilliermond, Ann. Sci. Natur. II Botan. **19:** 1, 1914; C. R. Soc. Biol. Paris **1:** 442. 1911.

Pellicle formed promptly in wort, no fermentation of any sugar, wort gelatin or malt extract gelatin liquefied within 21 days. Cells in wort 3–5 x 4–8.5 μ, pseudomycelium frequently formed. Asci arise after heterogamic conjugation or parthenogenetically; spores round, hemispherical or angular, approximately 2.5 μ in diameter. Nitrite negative; good growth and pellicle formation with ethanol as the sole carbon source. Maximum temperature for budding, in wort, 42–43° C.

Isolation: by Guilliermond from Biliwine (made from tubers of *Osbeckia grandiflora*) in West Africa.

Cultures examined: Guilliermond Lab. de Parasit. no. 617, through Harvard Collection no. 175; E. M. Mrak no. 1, orginally from Tanner's Collection.

[3] See also table 4 for a comparison of the species.

Klöcker's disposition of this species was approved by Stelling-Dekker, and nothing found in this investigation warrants further discussion here. A study of adaptation to various chemical environments in the growth of this species will be reported later in this paper.

2. Zygopichia Chevalieri var. **Andersonii** Nickerson nom. nov.

Zygosaccharomyces bisporus Anderson, Journ. Infect. Dis. **21**: 341, 1917, nec *Zygosaccharomyces bisporus* Naganishi, Bot. Mag. Tokyo **31**: 107–116, 1917.

Pellicle formed promptly in wort, no fermentation of any sugar, gelatin liquefied within 21 days. Cells on wort agar average 4 x 6.5 μ; no pseudomycelium formed on agar. Asci arise after heterogamic conjugation or parthenogenetically; spores round and smooth, approximately 2.0 μ diameter; very little variation from this average. Nitrite negative; good growth and pellicle formation with ethanol as the sole carbon source. Maximum temperature for budding, in synthetic medium and in wort, 39–40° C.

Isolation: by H. W. Anderson from human feces.
Culture examined: Guilliermond Lab. de Parasit. no. 569, through Harvard Collection no. 177.

An interesting coincidence occurred in 1917 when two men in widely separated parts of the world independently gave the same name to yeasts isolated by them. H. W. Anderson, in Urbana, Illinois, described one *Z. bisporus*, and H. Naganishi, in Tokyo, described the other. The first monographic treatment (Stelling-Dekker) after publication of these names accepted Naganishi's species and did not mention Anderson's. It is quite clear that Anderson and Naganishi did not describe the same yeast, for the latter's species complies with Stelling-Dekker's emendation of the genus *Zygosaccharomyces*, while the former's, as here shown, does not. Since it is not possible to determine which specific name has priority, the writer has been guided by Stelling-Dekker's acceptance of Naganishi's name.[4]

The culture of *Z. Chevalieri* var. *Andersonii* examined is believed to be a transfer of Anderson's original isolate. It is identical in all respects with Anderson's description. While this organism is closely similar to *Z. Chevalieri*, it is sufficiently different to warrant the varietal standing proposed. Similarities between the two forms are in regard to pellicle, absence of fermentation, gelatin liquefaction, mode of origin of asci, and approximate cell and spore sizes. Points of difference are that the proposed variety has smooth spores only, no pseudomycelial formation, and a maximum temperature for budding of 39–40° C. (this latter point a very small one, however).

3. Zygopichia Chevalieri var. **Barkeri** Nickerson var. nov. *Yeast G*, Pearce and Barker, J. Agric. Sci. Cambridge **3**: 55, 1908.

(From description given by Pearce and Barker.) In mediis maltatis membrana cito formatur; nullum saccharum fermentatur. Cellulae in mediis maltatis 4–5 x

[4] International Rules, Art. 57.

5–7.8 μ; in culturis altis multae cellulae non nihil longiores. Asci post conjugationem per cellulas formae similis pariunt; parthenogenesis quoque evenit. Sporum globosum leveque longitudo media lineae mediae 4.3 μ; spora post conjugationem formata solum in una duae cellulae reperiuntur. Calor maximus gemmandi 32.5° C.

(Description as given by Pearce and Barker.) Pellicle formed promptly in wort; no fermentation of any sugar. Cells in wort 4–5 x 5–7.8 μ; elongated cells in old cultures. Asci arise after conjugation of morphologically similar cells, or parthenogenetically. Spores round and smooth, average 4.3 μ in diameter; when formed after conjugation, are found in only one of the two gametes. Maximum temperature for budding 32.5° C.

Isolation: by Pearce and Barker from bottled English cider.
Culture examined: known only from the literature.

This organism was considered by Klöcker as belonging in *Zygopichia*, but he did nothing about its name. It is closely similar to *Z. Chevalieri* in pellicle formation, absence of fermentation, and approximate cell size in young cultures, with elongate cells in old cultures. Sufficient differences for the proposed varietal standing are found in possession of "physiological heterogamy" only, formation of only smooth spores, spore size, and the low maximum temperature for budding (32.5° C.).

4. Zygopichia farinosa (Lindner) Klöcker, *loc. cit.*

Saccharomyces farinosus Lindner, Woch. f. Brau. **11**: 152, 1894.
Pichia farinosa (Lindner) Hansen, Centralbl. f. Bakt. **12**: 529–538, 1904.
Zygosaccharomyces farinosus (Lindner) Papadakis, C. R. Soc. Biol. Paris. **86**: 447, 1922.

Prompt formation in wort of a thick, dry, wrinkled pellicle; ferments glucose, fructose, and mannose weakly. Gelatin not liquefied; nitrite test negative. Growth and pellicle formation with ethanol as sole carbon source. Cells in wort 2–5 x 4–16 μ, single or in budding chains; no pseudomycelium. Spores round to oval, and smooth, 2 x 3 μ; formed after isogamic or heterogamic conjugation or parthenogenetically. Spores have a refractile granule in center.

Isolated: by Lindner in Danzig from beer; by Saito from soy bean sauce.
Culture examined: ATCC no. 2252; originally from Tanner Collection.

This organism has had a rather checkered career. Discovered by Lindner, who considered it a *Saccharomyces*, it was shown by Hansen in 1904 to belong to *Pichia* on the basis of pellicle formation. This yeast was considered by Guilliermond as late as 1920 to have spores produced without conjugation, yet his student, Papadakis, in 1922 showed that a gametic conjugation was clearly involved, preceding spore formation. Klöcker, in 1924, on establishing the genus, removed this species from *Zygosaccharomyces* along with *Z. Chevalieri*. Since Stelling-Dekker has reaffirmed this species, and nothing has turned up in the course of this investigation to raise any question, nothing more need be said.

DOUBTFUL SPECIES

1. Zygosaccharomyces Guilliermondi Dufrénoy, Bull. Soc. Myc. Fr. **43**: 272, 1927.

(Description as translated from Dufrénoy.) Prompt pellicle formation in wort; no fermentation; gelatin not liquefied within 20 days. Asci originate after heterogamic conjugation or parthenogenetically; spores hat-shaped or smooth, averaging 2.0 μ diameter. Young cells in wort 3–5 x 6–9 μ; pseudomycelium formed on agar. Will grow in media containing 25% NaCl. Maximum temperature for budding is 34° C.

Isolation: by Dufrénoy in Corsica from the brine of the normal citron fermentation. Culture examined: known only from the literature.

Dufrénoy used Lindner's relatively inaccurate "little" method for studying fermentation of this yeast, and observed a slight fermentation of fructose, but none of glucose. Since it is highly unusual, if indeed possible, for an organism to ferment any sugar and yet not ferment glucose, it is here considered that this yeast actually has no fermentative ability. This form is closely similar to *Z. Chevalieri* in regard to pellicle formation, origin of asci, size and shape of spores, pseudomycelial formation, and lack of fermentation. It is doubtful that sufficient differences exist between the two to warrant varietal standing. It is a question whether this species should not be regarded merely as a salt adapted form of *Z. Chevalieri*, in view of the results of experiments on adaptation reported early in this paper. The time elapsed (20 days) in the judging of gelatin liquefaction as negative is somewhat shorter than one usually considers sufficient when working with yeasts. Preliminary findings which will be published at a later date indicate that high osmotic pressures have an inhibitory effect on proteolytic exoenzymes involved in gelatin liquefaction by two of the yeasts discussed here. This finding may possibly be of interest in view of the results obtained by Johnson et al (1942) on the effect of barometric pressure on the luciferase mechanism of phosphorescent bacteria. In any event gelatin liquefaction is an unsatisfactory character on which to differentiate a species because of our lack of knowledge concerning its distribution among yeasts and the influence environment may play upon it. In spite of this close similarity between *Zygosaccharomyces Guilliermondi* and *Zygopichia Chevalieri*, the author does not choose to reduce the former to synonymy with the latter at the moment. Dr. Dufrénoy, in a personal communication, informs me that his culture is possibly still in existence in the collection of Prof. Guilliermond at the Sorbonne. Until such time as the culture can be examined or is known definitely to be lost, decision may be reserved.

2. Zygopichia chiantigiana Castelli, Archiv f. Mikrobiol. **9**: 449–468, 1938.

(Description as translated from Castelli.) In malt after 24 hours at 25° C., cells globose or elongate, often slightly curved in the form of a sausage; cells usually contain a refractile globule; single or in groups of 5–6 cells. Average dimensions 3.8–4.5 x 7–9.5 μ. After 5 days cells elongate, frequently forming pseudomycelia. On malt agar, young cells

3.8–5 x 7–9 μ; many cells possess extruded tubes after 3 days. By 7 days heterogamic conjugation abundant with some asci formed parthenogenetically; usually 2 spores per ascus, spores globose or slightly flattened, usually containing a central refractile globule; average size 2.6–3 μ. On liquid media, as wine must or malt, a pellicle is rapidly formed, smooth and gray-white at first, it soon becomes strongly wrinkled and hazelnut in color. There is no fermentation of any sugar. Growth with ethanol is positive; scanty assimilation of nitrates; gelatin is not liquefied in 60 days; maximum temperature for budding 37° C.

Isolated: by Castelli from wine musts from the classic Chianti region and hills near Florence.

Culture examined: known only from the literature.

Castelli in his description of this species pointed out the close similarity to *Z. Chevalieri*, but was of the opinion that his organism differed sufficiently to warrant a new specific name. However, the characters used by Castelli to separate this yeast do not seem sufficiently strong to the writer to warrant such a separation. Cell size is a quite variable quantity with yeasts, and it is well known that the composition of the medium plays an important rôle in this variation. He is in error, in the writer's opinion, in saying that *Z. Chevalieri* forms only a weak pellicle (velo sottile) on liquid media. The writer has repeatedly obtained films with authentic cultures of *Z. Chevalieri* that could be described by the words used by Castelli for the pellicle made by his yeast. Gelatin liquefaction is a rather uncertain character for differentiating yeasts, as previously pointed out. Rather than reduce this organism to synonymy with *Zygopichia Chevalieri*, the author prefers to follow the course chosen previously, and await the time when it may be possible actually to examine this yeast.

3. Zygopichia Chevalieri var. **fermentati** Saito.

Such a species is listed in the 1940 catalogue of cultures issued by the Centraalbureau voor Schimmelcultures at Baarn. The author has been unable to find any reference in the literature to the name. It is listed here solely for the sake of completeness.

EXCLUDED SPECIES

The following species were placed by Klöcker in *Zygopichia*. Stelling-Dekker reclaimed them for *Zygosaccharomyces*, for, though they may produce a pellicle on liquid media, it is only after considerable time and under special conditions (as with high salt concentrations).

Zygosaccharomyces japonicus (Saito) Guilliermond, Rev. Gen. Bot. **20**: 32, 1908.
Zygosaccharomyces japonicus var. **soya** (Saito) Stelling-Dekker, *l. c.* 1931.
Zygosaccharomyces major var. **salsus** (Takahashi and Yukawa) Stelling-Dekker, *l. c.* 1931.

A study of cultures of these organisms, obtained from the American Type Culture Collection, or from the Northern Regional Research Lab-

oratory of the Dept. of Agriculture, showed that a pellicle is not formed promptly in ordinary sugar-containing liquid media. Stelling-Dekker's exclusion of these species from *Zygopichia* seems entirely justified.

DISCUSSION

At present the only character on which the genera *Pichia* and *Hansenula* are separated is that of nitrate utilization. As Mrak et al (1942) have pointed out, this is hardly a satisfactory condition, and they have revived, in part, Baltatu's (1939) suggestion of combining these genera as subgenera under some single generic heading.

Baltatu lumped *Pichia* and *Hansenula* together as subgenera of *Mycoderma* but his change has not been unequivocally received. To the writer it seems a mistake to place sporogenous yeasts in subgenera under an asporogenous genus. It would be a much better practice to combine the sporogenous genera and to allow the imperfect or asporogenous genera, in this case *Mycoderma*, to stand until their perfect stages have been clearly demonstrated.[5] Using grape must, Baltatu claimed to have induced sporulation in fourteen species of *Mycoderma*. While it is highly possible that the future might see the discovery of spores in other individuals of this imperfect group, it is preferable to transfer at such time the species involved to the perfect group rather than to align them in their entirety at the present time.

Since the name *Pichia* has priority over *Hansenula* in point of time of establishment and would take precedence in the event of a merging of these genera, the writer feels justified in adding to the literature the combinations proposed in this paper. While data on nitrate utilization are not available on two of the forms discussed, the writer is of the opinion that the close similarity between the proposed variety *Barkeri* and the parent species is sufficient justification for its inclusion here.

To the author, it seems more satisfactory to test for the presence of nitrite than to report on the extent of growth with nitrate as the sole source of nitrogen. Excellent tests for nitrite, a reduction product of nitrate, exist (c. f. Manual of Methods, 1942). By using one such (sulfanilic acid and α-naphthylamine), it was found that all cultures of *Zygopichia* examined were completely negative; 3 species of *Pichia* examined were also negative, while 4 species of *Hansenula* and one of *Zygohansenula* gave the brilliant reddish color of a positive test for nitrite, signifying nitrate reduction. The usual difficulty in testing for nitrate *utilization* is that in eliminating sources of nitrogen other than nitrate from the culture medium, one invariably eliminates all sources of growth-nutrilites. Since the test is not to see if the yeast can grow in the absence of "bios," and since it is rather troublesome and expensive for routine work to make up a solution containing the known growth nutrilites as pure chemicals, the author feels it is preferable to permit yeast growth

[5] See International Rules, Art. 57.

by adding a trace of yeast extract (0.10 g/liter) to a medium consisting otherwise of salts, glucose, and KNO_3. Yeasts negative for nitrite make a meager growth, while yeasts that reduce nitrate flourish. Since the results of the nitrite test are clear-cut, it obviates the necessity of describing the amount of growth in words. In cases where the nitrite test was negative, it was found, using the zinc dust test, that nitrate still existed as such in the medium, thus precluding the rather obscure possibility that nitrate had been reduced beyond the nitrite stage.

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1(3): 483–488 FARLOWIA January, 1944

A NEW GENUS OF THE SCLEROTINIACEAE

H. H. Whetzel [1]

My conservative critics will doubtless raise an eyebrow at this presentation of another monotypic genus in that group of stromatic inoperculate Discomycetes for which I have erected the family *Sclerotiniaceae*.[2] When I began my studies on these forms, now some 30 years ago, mycologists treating any of these species commonly tossed them more or less indiscriminately into one of three or four genera, most frequently into *Sclerotinia* or *Ciboria*, genera erected by Fuckel back in 1869. My investigations on these forms indicate that there are at least 15 or 20 well marked generic groups in this family. Those which appear to me to have acceptable generic status are: *Sclerotinia*[3] Fuckel 1869; *Ciboria*[3] Fuckel 1869; *Rutstroemia* Karsten 1871 (in part) emend. Rehm 1893;[4] *Stromatinia* Boudier 1907;[5] *Phaeociboria* von Höhnel 1918;[6] Lambertella von Höhnel 1918 (see also Whetzel 1943); *Monilinia* Honey 1928; *Septotinia* Whetzel 1937; *Ovulinia* Weiss 1940; and *Martinia* Whetzel 1942. It will be evident to my incredulous reader that I still have a substantial number of genera up my sleeve which I hope to spring upon the mycological public shortly. Of the ten above listed genera, four are as yet monotypic, but as I discovered in the case of *Lambertella*, they are likely to lose that status as more intensive searches in the field uncover undescribed species of the *Sclerotiniaceae*.

With this orientation of my critical mycological fellows, I shall now proceed to add another monotypic genus to this growing family.

A COPROPHILOUS SPECIES

While on a collecting trip with some of my students at Malloryville, New York, on June 22, 1942, I picked up a small dung-ball, about half an inch long by a quarter of an inch in diameter among leaf mold on the hillside about the pitcher plant bog. The dung-ball looked like that of a partridge. It bore several tiny brown apothecial cups borne on the tips of long hair-like stipes. Ascospore shootings on potato dextrose agar gave a striking, black, indeterminate stroma (Fig. 2–3) from which there presently developed numerous long-stipitate apothecia like those on the original substrate.

[1] *Acknowledgments:* I am grateful to Drs. David H. Linder and W. Lawrence White for critical suggestions in the preparation of this paper and to Dr. Rolf Singer who has kindly written the Latin descriptions.

[2] See Whetzel, 1943, p. 18, footnote 2.

[3] Both these genera need to be revised and emended with *Sclerotinia sclerotiorum* (DBy) Fckl. and *Ciboria caucus* (Rebent.) Fckl. to be taken as type species respectively.

[4] See White, 1941, p. 163, 169.

[5] To be restricted to forms similar to the type species, *S. rapulum* Boud.

[6] See Whetzel and White, 1940, p. 614.

The dung-ball, meanwhile in a moist chamber, failed to produce more apothecia and was discarded. The striking characters of the apothecia which developed so abundantly from the stromata produced on the agar substratum lead to a careful study of the species which proves to be quite unlike any other of the fifteen or more genera of the *Sclerotiniaceae* known to me. I am, therefore, describing it as a new species and placing it in a new genus.

Coprotinia gen. nov.

Stromate indistincto, nigro, 1–2 mm. crasso; strato corticali 1– vel pluri-stratoso, ex hyphis dense intertextis, atris consistente, medullam includente. Structura stromatis structurae sclerotiorum *Botrytis cinereae* simillima. Carpophoris spermatigeris haud visis. Statu conidiali nulla. Apotheciis gregariis, longis, stipitibus gracilibus institutis, plus minusve fuscidulis; disco exiguo prae stipitis longitudine, margine fortiter recurvato in maturis, stipite criniformi, apicibus hypharum glanduliformibus ornato; ascis minutissimis, clavatis, basin versus gradatim attenuatis, apice incrassatis, poro iodi ope leviter caerulescente; ascosporis bi-seriatim dispositis, in apicem asci congregatis, minutis, elongate ellipsoideis, uni-cellulatis, hyalinis; paraphysibus cylindraceis et tenuiter tunicatis.

Stroma (on potato dextrose agar) indeterminate, black, 1–2 mm. thick; *rind* (external and submerged) one to several layers of densely interwoven, slender, dark brown to black hyphae, enclosing a medulla; *medulla* of rather closely interwoven, slender, thin-walled hyphae embedded in a rubbery transparent matrix. Stromatic structure very like that of the sclerotia of *Botrytis* of the *cinerea* type. *Spermatial* fruit-bodies not seen. *Conidial* stage wanting. *Apothecia* gregarious, long, slender-stipitate, some shade of brown; *disc* small in comparison with length of stipe, the margin strongly recurved at maturity, *stipe* hair-like, the surface adorned with scattered glandular hyphal tips; *asci* very small, clavate, tapering gradually to the base, apex thickened, pore faintly J+; *ascospores* biseriate, crowded into the swollen apical part of the ascus, minute, long ellipsoid, one-celled, hyaline; *paraphyses* cylindric and thin-walled.

Coprotinia minutula sp. nov.

Stromate diffuso, indistincto, nigro, 1–2 mm. crasso; strato corticali ex hyphis dense intertextis, atro-fuscis, gracilibus consistente et uno vel nonnullis stratis composito, extus asperulato; medulla ex hyphis intertextis, ramosissimis, anastomosantibus, gracilibus, septatis, hyalinis, 3–3.5 μ crassis efformata. Carpophoris spermatigeris haud observatis. Statu conidiali nullo. Apotheciis numerosis e superficie tota stromatis nusquam non enatis, longissime stipitatis; receptaculo 1–2 mm. in diametro, atrocastaneo ad primam maturitatem, vetustis expallentibus usque ad colorem pallide fulvidum, tenui, margine prima juventute fortiter recurvato; stipite gracillimo, criniformi, usque ad 20 mm. longo et ¼ mm. crasso, sursum pallido, atro deorsum, apicibus hypharum glanduliformibus ornato; ascis brevibus, crassiusculis, clavatis, saepe conspicue inflatis sub ipso apice, 31–47 x 3.6–4.8 μ, apice rotundato, incrassato, poro iodi ope leviter caerulescente; ascosporis 8, minutis, biseriatim dispositis et in tertiam superiorem inflatam congregatis, elongate ellipsoideis, 4.8–6.0 x 1.5–2 μ, hyalinis; paraphysibus cylindraceis, tenuiter-tunicatis nec septatis nisi ad basin, 3–3.5 x 33–45 μ.

Stroma (on potato dextrose agar) diffuse, indeterminate, black, 1–2 mm. thick (Fig. 2–3); *rind* (external and submerged) composed of densely

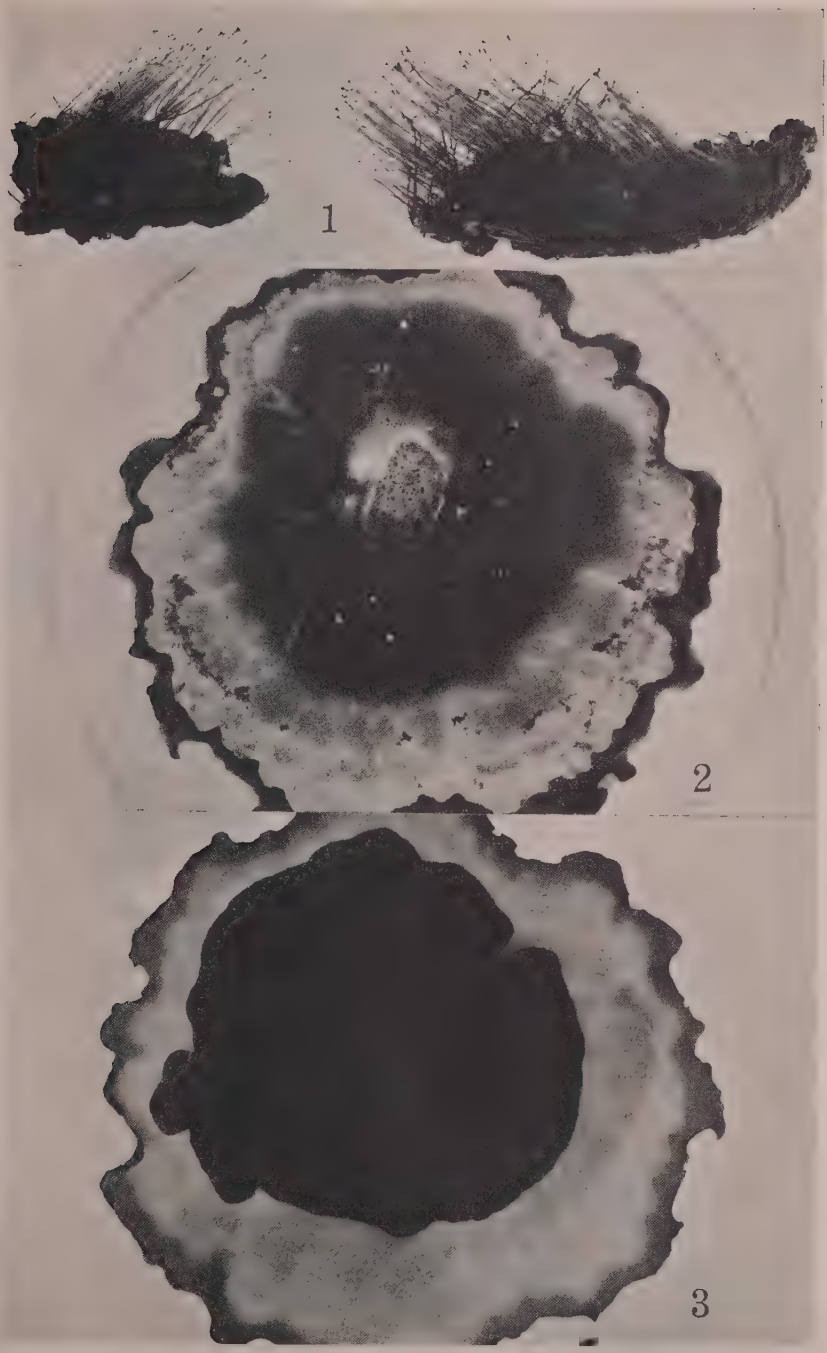

Fig. 1–3. Coprotinia minutula: 1, Apothecia produced in culture, × 2; **2,** Stroma formed on potato dextrose agar, photographed from upper surface, × 1; **3,** Same as 2 but photographed with Petri dish inverted, × 1.

interwoven dark brown, slender hyphae, one to several layers thick, the external portion here and there double with narrow strip of medulla between the two layers; the surface rough and where not imbedded in the agar covered with a felty layer of loose brown hyphae; *medulla* of rather densely interwoven, much branched and anastomosed, slender, thin-walled,

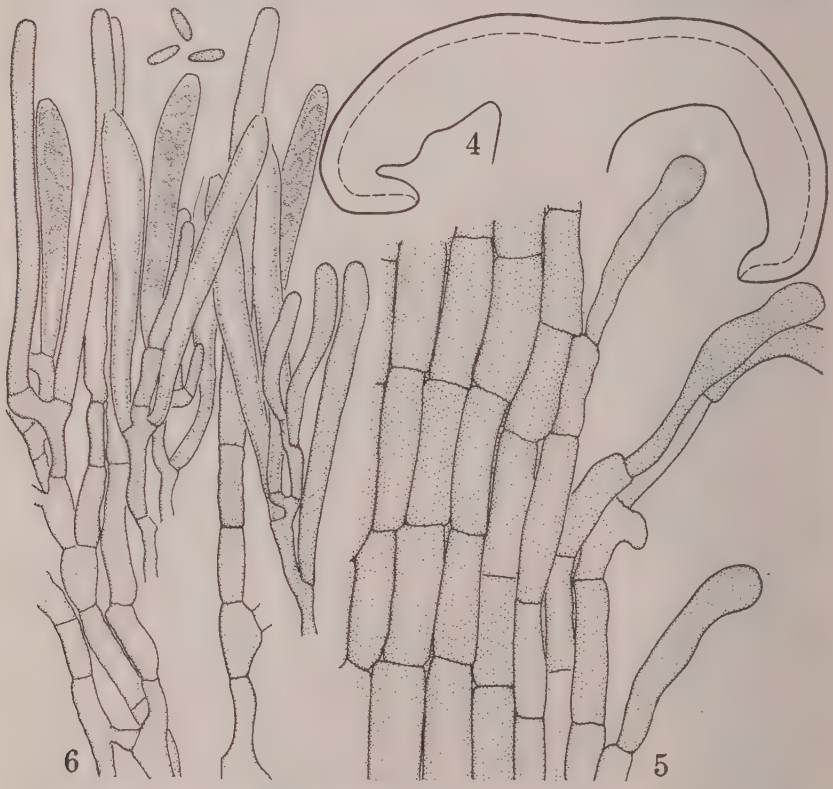

Fig. 4–6. Coprotinia minutula: 4, Diagram of section through disc showing its general form at complete maturity, × 80 approx.; **5,** Longitudinal section from lower part of stipe showing structure of stipe and protruding hyphal tips, × 1290; **6,** Asci, paraphyses, and ascospores, × 1290.

septate, hyaline hyphae, 3–5.5 μ in diam., embedded in a transparent rubbery matrix. *Spermatial fruit-bodies* not observed. *Conidial* stage wanting. *Apothecia* arising in large numbers from all over the surface of the stroma (Fig. 1), very long stipitate; *receptacle* 1–2 mm. in diam., dark chestnut brown when first mature, bleaching out to "pale ochraceous tawny" (R) with age, thin, the margin very soon strongly recurved giving the appearance of tiny toadstools; *stipe* very slender, hair-like, up to 20 mm. long by ¼ mm. thick, pale above, dark below, adorned with short glandular hyphal tips; *asci* short, stout, clavate, often markedly

inflated or swollen just below the tip, 31–47 x 3.6–4.8 μ, apex rounded, thickened, pore faintly J+; *ascospores* 8 per ascus, minute, biseriate and crowded into the swollen upper third of the ascus, narrow ellipsoid, 4.8–6.0 x 1.5–2.0 μ hyaline; *paraphyses* cylindric, thin-walled and aseptate except at the base, 3–3.5 x 33–45 μ.

HABITAT: Collected only once on a small dung-ball of some unkown animal at Malloryville, N. Y., June 22, 1942. Known chiefly from stromata and apothecia developed in cultures derived from ascospore discharge on potato dextrose agar and on sterilized wheat in laboratory at Ithaca, N. Y.

TYPE SPECIMEN: C. U. Pl. Path. *31585*. Stromata developed on potato dextrose agar and on sterilized wheat kernels.

This little discomycete presents several distinctive characters. Coprophilous species in the *Sclerotiniaceae* are rare. The only other species known to me to occur on dung is the form recorded by me[7] but collected by R. F. Cain on rabbit dung near Lac St. Joseph, Quebec, on August 25, 1938 (C. U. Pl. Path. *29646*). That form I have referred to *Martinia panamaensis* Whetzel. The species here described is, however, quite different since the apothecia develop from a diffuse stroma rather than from tiny distinct hemisphaerical sclerotia, and the spores are hyaline instead of colored.

In certain of its aspects, *Coprotinia minutula,* reminds one at once of certain species of *Lambertella.* It cannot, however, be referred to that genus, since its stroma is of a more highly developed type, being in the structure of its rind and that of its medulla much more like the sclerotium of a *Botrytis* of the *cinerea* type. This, together with its colorless spores, sets it off not only from *Lambertella* but also from *Martinia,* although its apothecia, asci and ascospores are strikingly like those of the latter genus. It is perhaps most closely related to *Rutstroemia,* but the slender hair-like stipes of the apothecia would seem to deny reference of it to that genus. One of its most peculiar characters is the gland-like hyphal tips which adorn the stipe throughout its length and over the underside of the receptacle. These are of variable length, usually of 1 to 5 short cells, the apical cell being swollen and filled with an olivaceous-green substance of an oily character (Fig. 5).

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[7] See Whetzel, 1942, p. 589.

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1(3): 489–490 FARLOWIA January, 1944

BOOK REVIEWS

THE BOLETACEAE OF NORTH CAROLINA. By William Chambers Coker and Alma Holland Beers. Chapel Hill, University of North Carolina Press, 1943. viii, 96 pp. pl. 1–65, frontispiece. $7.00.

The authors include three genera in this treatment: *Boletus*, *Boletinus*, and *Strobilomyces*, all understood in a conservative sense, i. e., *Boletus*, by far the largest, with seventy species indicated and described for North Carolina, *Boletinus* with five species, and *Strobilomyces* with one species. The book is abundantly illustrated with many good and some excellent photographs, six plates in colors, five plates of spore drawings and one text illustration, showing the anatomy of several species. Some of the colored pictures are quite natural, and thus very helpful to the beginner. The microscopical pictures, however, are much too schematic and therefore of comparatively little help. Cystidia (with one exception), basidia, tramal hyphae, the covering layer of pileus and stipe, as well as chemical reactions are neither illustrated nor mentioned in the descriptions. The exact color of the spore print, a frequently neglected but very valuable character, is correctly indicated in nearly all descriptions. Two keys, both mainly based on macroscopical characters, are useful for everyone who tries to determine Boletes, although in a few instances they may lead the less experienced into trouble because they are not dichotomous, and therefore difficult to use.

Those who are not primarily interested in taxonomy may regret the lack of common names in the book, as well as the lack of indications concerning the practical interest of the species described. The authors mention only casually that "this is one of the safest groups . . . for the beginner to experiment with, as only a few species are now thought to be poisonous." The warning to keep hands off the whole *Miniato-olivaceus* group and all of the Luridi can be heartily subscribed to. Many a lay reader, however, may desire more information on the value of the single species for gastronomic purposes, while foresters and ecologists would appreciate more specific data on the important problem of mycorrhizal relationship between forest trees and Boletaceae.

The taxonomist, on the other hand, will find it difficult to follow the authors in many of their solutions of questions of nomenclature as well as in the general arrangement of the species. He will also regret the little space that has been devoted to synonymy, and the absence of Latin diagnoses for the new species and varieties proposed (*Boletus felleus* var. *minor* var. nov., *B. satanas* var. *americanus* var. nov., *B. viridiflavus* spec. nov., *B. sub-fraternus* spec. nov., *B. parvulus* spec. nov., *B. americanus* var. *reticulipes* var. nov., *B. subaureus* var. *siccipes* var. nov.). The interpretation of some species of *Boletus* does not seem to be in accord with the original concept of their authors, as, for example, *B. luridus* Schaeffer which is evidently different from the plant described under this name in Europe, as the authors themselves seem to feel.

Notwithstanding certain shortcomings mentioned above, the book contains much valuable information for a wide variety of people interested in the study of Higher Fungi, and should be warmly welcomed not only in North Carolina, but also in other Eastern States, and especially in the South where the Boletaceae-flora, though rich and interesting, has never been monographed before. — R. S. and D. H. L.

PLANTS AND VITAMINS. By W. H. Schopfer [translation by N. L. Noecker] Waltham, Mass. Chronica Botanica. 1943. ix, 293 pp. illus. $4.75.

It may appear unusual to review in a taxonomic journal a book which deals primarily with a physiological subject, but after reading the book on plant vitamins, one can not help but be impressed by the part that taxonomy has had in the development of this field of research, and conversely, one is equally struck by the service that a knowledge of vitamins may render to taxonomy by making possible the more normal

growth of organisms that have hitherto been grown on incomplete nutrient substrata. Anyone who has tried to determine fungi from cultures can readily realize what it would mean to have a medium on which these organisms would grow and behave as they do in nature. Thus, for those who deal with organisms in culture, whether or not they have sufficient chemical knowledge to understand the chemistry of vitamins, there may be found ample reason for reading this book and garnering facts that will be of service in their investigations since the author deals not only with the rôle of vitamins in the nutrition of the higher and lower plants, but also introduces facts and suggestions on the part these substances play in symbiotism and parasitism. But lest it be thought that only taxonomists may find food for thought in this excellently presented and up-to-date summary of our knowledge of plant vitamins, it should be emphasized that throughout the work the author, while dealing with the occurrence, nature, and function of vitamins and kindred substances, has throughout presented many suggestions which should inspire further research in the allied fields of physiology, biochemistry, and genetics. Biologists are greatly indebted to the author for this valuable compilation of facts that have been presented in a careful yet stimulating manner, and to the publisher and translator who have made this work available in English at a time when biological discoveries may mean so much. — D. H. L.